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SURGERY
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MODERN WARFARE

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CHAPTER XLVIII

ANÆSTHETIZING THE WOUNDED

IT should be the aim of surgical units working under war conditions to bring to the treatment of casualties all that was best in pre war procedure This applies not only to surgical technique but also to the important ancillary service of anæsthetic administration

Has the stress of war conditions been such as to negative the use of modern anæsthetic methods? Langton Hewer answering this question stated that the anæsthetic service was of the highest peace time order when the wounded from the Dunkirk evacuation were being treated and later during the period of intensive air raids the service in the E.M.S hospitals was never so overstrained as to lower the existing standard in respect of personnel equipment or technique

In the zone of actual military operations the rapid movement of the modern battle must mean less equipment and simpler methods but even there the anæsthetist may still employ endotracheal anæsthesia in a simplified form or use up to-date intravenous agents or spinal block analgesia in order to facilitate the surgeon s work and secure an approximation to home standards

Are there any special anæsthetic problems associated with casualty work? This question may be considered (*a*) in relation to working conditions and equipment and (*b*) in relation to the wounded and their injuries

(*a*) **Problems related to working conditions and equipment**—The change from the air conditioned or at least well ventilated operating theatres of peace time to the stuffy blacked-out gas proofed emergency theatres of war time is one to which most surgeons anæsthetists and their associated personnel have now become acclimatized The difficulties of ventilation and temperature regulation and the high humidity however do make the work much more irksome

Accumulation of anæsthetic vapours vitiate the atmosphere still more and in addition ether divinyl ether and ethyl chloride are inflammable and in certain proportions with oxygen are potential explosives Ethylene and cyclopropane are in the same category The use of extractor fans the earthing of all apparatus anæsthetic and electrical and the administration of the anæsthetic agents by means of closed circuit apparatus will do much to eliminate fire and explosion risks

Boyle s apparatus (Fig 370) is an efficient gas oxygen and ether machine to which a CO_2 absorber unit (B) has been attached and it provides the closed circuit type of anæsthesia referred to above Closed circuit anæsthesia has among several advantages that of economy an important feature in war time when supplies may at any time be suddenly curtailed

Figures showing the relative consumption of a Boyle's machine, open and closed, are as follows —

	N_2O	O_2	Ether
Open method	17.3 gals	5.1 cub ft	5.1 oz
Closed method	8.2 ,,	1.27 ,,	2.2 ,,

With the newer type of Boyle's machine the following overall figures were obtained (Evans) —

	6 gals	0.7 cub ft	0.8 oz

These figures are taken from parallel series of about 150 cases each and are all based on total quantities used. No deduction has been made for leakage or other loss.

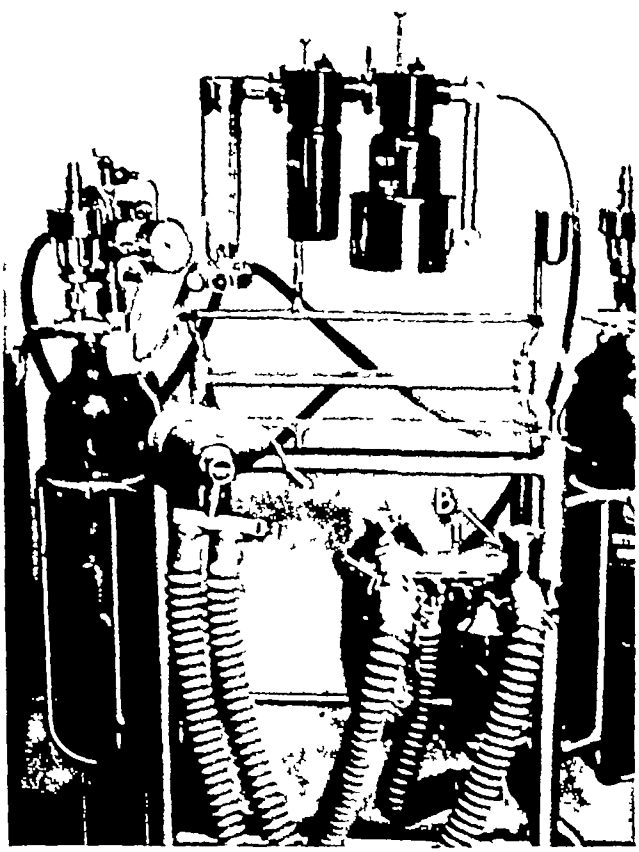

FIG 376

Standard pattern Boyle's machine with (A) basal oxygen rotameter and (B) CO_2 absorber circuit (Charles King) Both units of plug-in type and interchangeable with ordinary Magill unit

Goldman's visible drip-feed attachment (Fig 377) for

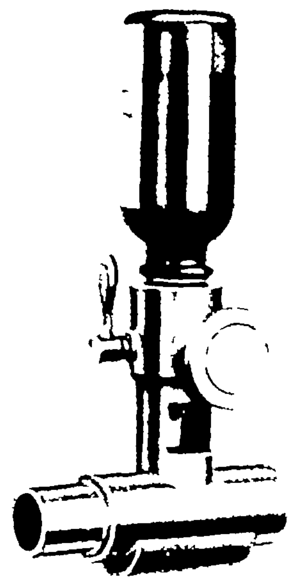

FIG 377

Goldman's drip feed

divinyl ether is useful but is easily broken unless handled with care

Face masks, tubing and airways must be cleaned thoroughly between cases and may be kept in 1 : 8,000 biniodide before drying and using again. Reserve stocks of drugs should be kept in multiple small depots rather than in one storeroom. If possible the small storerooms should be underground, dark, cool and in such a position as to present no danger of fire.

Whilst on the home front the problems related to working conditions are mainly those of difficult ventilation and its sequelæ, the anæsthetist serving in the battle zone has to circumvent the additional problem of meagre equipment. He must carry on without gas and oxygen cylinders and all the modern refinement of technique associated with closed circuit apparatus. Nevertheless there is still an adequate choice of methods left for him

Spinal block analgesia intravenous anaesthesia with pentothal sodium or some of the evipan substitutes are available in addition to inhalational anaesthesia by means of the ordinary gauze-covered mask No matter how limited the equipment however the anaesthetist should make sure that it includes a number of Magill endotracheal tubes of assorted sizes with the appropriate metal connections Thus equipped he can when necessary (*e.g* for operations on the head and neck) provide endotracheal anaesthesia for—one hopes—an appreciative surgeon

Two simple improvisations for administering air-ether by the endo-

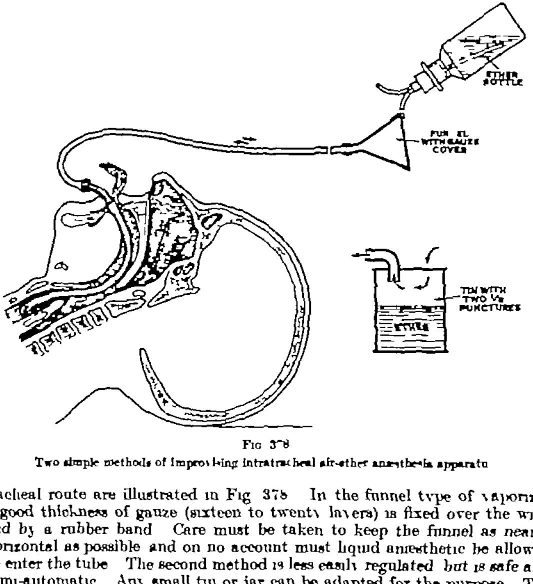

FIG 378

Two simple methods of improvising intratracheal air-ether anaesthesia apparatus

tracheal route are illustrated in Fig 378 In the funnel type of vaporizer a good thickness of gauze (sixteen to twenty layers) is fixed over the wide end by a rubber band Care must be taken to keep the funnel as nearly horizontal as possible and on no account must liquid anaesthetic be allowed to enter the tube The second method is less easily regulated but is safe and semi-automatic Any small tin or jar can be adapted for the purpose The rubber tubing connecting the endotracheal tube to the funnel or canister must be kept as short as possible because it is all dead space and CO_2 accumulates in it Proper oxygenation is difficult to maintain if the tube is very long

Oxford Vaporizer No 1—The new ether vaporizers which have been evolved by Macintosh and his co workers at Oxford and which are to be

(b) **Problems related to the wounded and their injuries**—For the experienced anæsthetist accustomed to dealing with all types of surgical emergencies which enter the large hospitals in normal times there are really no new problems but for the anæsthetic service as a whole the large numbers of serious casualties that have to be dealt with at one time may constitute a major problem Under war conditions the proportion of critical cases to the number of anæsthetists competent to deal with them is very much higher than in ordinary times It is essential therefore that anæsthetists less experienced in the anæsthesia of urgent surgery should make themselves proficient in the special techniques which reduce to a minimum the detrimental features associated with anæsthesia and promote certain factors that are relatively beneficial

The following general considerations of the main factors influencing or modifying anæsthetic procedure may help the less experienced anæsthetist to a better understanding of what is involved in the administration of anæsthetics to the seriously injured

When casualties occur in large numbers at one time there is considerable delay before many of the victims can be transported to hospital Such delay entails an increased period of exposure to cold and possibly wet and a longer exposure to physical pain and mental stress all of which contribute very considerably to the state of shock already initiated by the physical injuries The surgeon is well aware of the much increased risk which attends operative intervention on shocked patients and unless the urgency is extreme anti-shock measures are instituted by him at the earliest possible moment and operation delayed until the patient's condition has improved to the optimum extent which his injuries will allow The anæsthetist should if possible see the patient at this time and in collaboration with the surgeon decide on what sedative may be necessary In doing so he must realize that in cases of profound shock depressant drugs are definitely harmful and prejudicial to the patient's ultimate recovery Morphia in a dose not exceeding ¼ gr may be given to relieve pain when present or intramuscular luminal (1 to 2 gr) is useful to allay fear and restlessness and induce sleep when psychical factors predominate

While anti shock measures will improve the patient's condition the anæsthetist must remember that any necessary operative procedure will tend temporarily to nullify the improvement and he must consider his choice of anæsthetic with due regard to this probability In short he must choose an anæsthetic which as far as possible will not contribute further to the shocked state because of its toxicity or mode of action The anæsthetist's part during operation is to help to prevent additional shock What are the factors which contribute to this additional shock? They are sensory stimuli from the operation field hæmorrhage loss of body heat and fluids through the skin and by exhalation and deficient oxygenation due to sluggish pulmonary circulation when the patient is in the recumbent position Bombardment of the thalamus and cerebral cortex by sensory stimuli can only be positively prevented by regional nerve block or local infiltration and where the nature and extent of the operation will permit this must be recognized as a method of the highest value and importance Where the injuries to be treated are widespread and extensive the method

may not be practicable because there are limits to the amount of the analgesic agent which may be used. The amount of ½ per cent. procaine or novocain should not exceed 150 c.c., but such a quantity is adequate for most operations, especially if regional nerve block rather than massive local infiltration is employed whenever possible.

The objection that the method is a time-consuming one cannot be sustained.

The scope of spinal block analgesia may suitably be discussed at this juncture. Like local analgesia, spinal block protects the patient against shock-producing stimuli but it also produces sympathetic paralysis in the segments involved and this causes a reduction in the volume of the circulating blood. In a severely shocked patient whose blood pressure is already low, the further fall may lead to a cerebral anæmia of such degree as to depress the vital centres beyond the limits compatible with life. Therefore, in the presence of shock and especially if the patient is suffering from penetrating wounds of the abdomen, spinal block analgesia must not be used.

In traumatic surgery spinal block analgesia should be limited to operative procedures on the lower limbs.

Combined local analgesia and general anæsthesia.—The value of local analgesia from the standpoint of protection against shock-producing stimuli has been stressed but the surgeon and anæsthetist will recognize that the advantages may be nullified by the potent psychic factor which will be present if the patient is too conscious of what is going on. The abolition of consciousness by nitrous oxide and oxygen eliminates the psychic factor, and the combined method is the practical application of the "Anoci-association" theory formulated by Crile in 1920. The post-operative fitness and comfort of patients operated on under the combination of local analgesia and gas-oxygen "sleep" compares more than favourably with that following any other form of anæsthesia.

It has been indicated already that the anæsthetist has a duty to perform in helping to prevent aggravation of shock during operation. General anæsthesia with nitrous oxide and oxygen or cyclopropane and oxygen, enable him to do so. Where possible the use of toxic drugs such as chloroform and ether ought to be avoided, because their presence in the blood and tissues interferes with oxidation. Owing to their depressant effect on the respiratory and circulatory centres and by virtue of their lipoid solubility, which hinders efficient gaseous exchange, they increase the tissue asphyxia already present in the shocked patient. Fortunately, the shocked patient is much less sensitive to pain and therefore anæsthesia is attainable by the use of less toxic agents. By using nitrous oxide and oxygen in a semi-closed apparatus such as the Boyle, anæsthesia can be maintained, while at the same time factors such as low blood pressure, cyanosis and the loss by exhalation of water vapour and heat may be mitigated. The circulation is supported and the blood pressure maintained by the increased respiratory excursion and better expansion of the lungs which results from partial rebreathing. By the same mechanism the cyanosis present before operation is eliminated and any tendency to hypostatic congestion counteracted. It is a constant observation that the shocked patient looks better once he is under the influence of gas and oxygen. Owing to the lowered metabolic rate which is concomitant with shock, anæsthesia can be

maintained on gas and oxygen mixtures in which the oxygen may form as much as 20 to 25 per cent If the anæsthesia is insufficient as for example it might be in an abdominal section the safest supplement is local infiltration or intercostal nerve block to obtain the necessary relaxation of muscles When a closed circuit CO_2 absorption apparatus is available cyclopropane and oxygen may be used and will provide a sufficient depth of anæsthesia even for abdominal operations Cyclopropane is administered with a high proportion of oxygen (85 per cent approximately) an important factor when the volume of circulating blood is reduced If cyclopropane is not available then ether or divinyl ether may be used to supplement gas and oxygen when necessary Much less harm is done to the patient by a little supplementary ether than by attempts to maintain gas and oxygen anæsthesia on a drastically reduced oxygen content

Intravenous anæsthesia — The intravenous barbiturates — pentothal sodium and the British substitutes for evipan—have proved of great value as anæsthetic agents for the lesser surgical procedures in casualty work They have a claim to usefulness in major surgery also but only when there is sufficient time for a skilled anæsthetist to devote his complete attention to each case Through the medium of an intravenous drip the barbiturate may be administered over a fairly long period but in such cases the anæs thetist must ensure adequate oxygenation by insufflation of oxygen if necessary and so counteract the deleterious effect of prolonged respiratory depression which frequently accompanies such administration For this reason the method cannot be a first choice for shocked cases

The main sphere of usefulness for the barbiturates is in the treatment of minor injuries such as the cleansing of superficial wounds and in short procedures (twenty to thirty minutes) such as reduction of simpler fractures and application of plaster

Choice of anæsthetic—For operations about the head and neck endo tracheal anæsthesia is essential in order that the surgeon may have free access to the operation field In cases of severe head injury when the patient is unconscious an anæsthetic is not required but it is a wise precaution to intubate the larynx so that in the event of respiratory failure from increasing intracranial tension the anæsthetist can connect the tube to the gas and oxygen machine and immediately start rhythmic inflation of the lungs with oxygen by compression of the rebreathing bag of the apparatus Anæsthesia for operations on the head and neck need not be carried deeper than the first plane of the third stage and for this nitrous oxide and oxygen is sufficient after a small pre-operative dose of morphine and hyoscine For long intracranial operations involving the raising of large osteoplastic flaps local infiltration supplemented by gas and oxygen sleep to allay the restlessness of the patient is the method of choice

Operations on the chest wall may be performed under local analgesia or under light general anæsthesia For work inside the pleural cavity endo tracheal cyclopropane and oxygen, or gas oxygen and minimal ether are used and preferably by closed circuit apparatus so that the intrapulmonary pressure and the extent of the respiratory excursion may be to some extent controlled by the anæsthetist If diathermy apparatus is to be used inside the pleural cavity cyclopropane or ether must not be used If nitrous oxide and oxygen

is insufficient in such circumstances, then a small supplementary quantity of chloroform may be added

In traumatic abdominal surgery, inhalation anæsthesia with nitrous oxide and oxygen supplemented by local infiltration or intercostal nerve block is the method of choice, especially in the presence of shock. Alternatively, cyclopropane and oxygen may be used, and in cases exhibiting little or no shock, gas oxygen and ether may be necessary because the threshold of the patient's resistance to anæsthesia has remained at its normal level

Dislocations, fractures and associated lacerations of the soft tissues are best treated under light general anæsthesia, but it must be sufficient to allow the surgeon to overcome muscular contraction in his manipulations If marked shock is present, nitrous oxide and oxygen should be used but where there is only slight shock ether may be added if required Care must be taken during the induction stage lest the patient struggle and convert a simple fracture into a compound one

Burns form a large proportion of the casualties of modern warfare The treatment of extensive burns usually takes some considerable time, and the anæsthesia, therefore must be minimized as much as possible Such cases are generally seriously shocked and show diminished sensibility to pain The only anæsthesia required if it can be called anæsthesia is light gas and oxygen " sleep "

Conclusion--This chapter has dealt mainly with the major problems of anæsthetic administration, but the anæsthetist's duties are not restricted to the anæsthetic room and operating theatre He has many minor problems to deal with each quite important in itself but of which limitation of space prevents discussion

He must arrange the pre-medication for each individual case and find beforehand any special features in the patient's history or state on examination which may influence the choice of anæsthetic, and possibly even the nature and extent of the operation He must be able to give instructions regarding the pre-operative preparation of the unstabilized diabetic or the patient with a fibrillating heart

His versatility must embrace dexterity in applying a tourniquet (and remembering to take it off again), the ability to set up an intravenous drip if called upon to do so, and the complete mechanical knowledge required to look after reducing valves, flowmeters and suction plant

Finally, he is responsible for the proper care of the patient on the return journey to bed and must be ready to advise regarding treatment for anæsthetic sequelæ such as vomiting, respiratory and circulatory depression and chest complications if and when they occur

CHAPTER XLIX

CHEMOTHERAPY

THE introduction of modern chemotherapy in the treatment of acute microbic infections has resulted in a confused terminology often apparent in medical literature The general term sulphonamides is rightly applied to the group of compounds now in common use but distinction must be drawn between individual members of the group since there is considerable difference in their nature and the scope of their action

In addition to the sulphonamides other compounds termed sulphones have been the subject of much study and some clinical trial but their exact place in therapeutics has not yet been determined

COMPOUNDS AVAILABLE FOR USE

The basis of all sulphonamides in general use at present is para-aminobenzenesulphonamide or sulphanilamide and as such this is sold under a variety of different names, such as Streptocide Sulphonamide P P.A B S., Colsulanyde Prontylin, Ambesid and Prontosil album of German origin.

Derivatives of sulphanilamide have been prepared for the purpose of making compounds suitable for parenteral therapy ; others have been discovered which have a wider range of activity or are less toxic than sulphanilamide itself. An example of the last group is benzyl sulphanilamide otherwise known as Proseptasine or M & B 125 The soluble derivatives of sulphanilamide include di-sodium p-(γ phenyl-propyl-amino)-benzenesulphonamide alpha-γ-disulphonate commonly known as M & B 137 or Soluseptasine Sulphonamide E.O.S., and Sulphonamide L.S F and solutions of sulphanil amide in organic solvents such as Streptocide solution.

A soluble sulphone diamino-diphenyl sulphone glucoside or Promin has recently been introduced

Sulphanilamide derivatives which have a wide range of activity are 2-sulphanilylaminopyridine (otherwise sulphapyridine Dagenan or M & B 693), 2 sulphanilylamino-thiazole (also known as sulphathiazole Thiazamide or M & B 760) sulphacetamide (synonymous with Albucid), together with their sodium salts for intravenous and occasional intramuscular administration Recently two further sulphonamides have been introduced, namely sulphanilylguanidine and 2-sulphanilylamino-pyrimidine (generally known as sulphadiazine) but their value has not so far been fully evaluated.

GENERAL CONSIDERATIONS GOVERNING CHEMOTHERAPY

It is impracticable to discuss the treatment of all the bacterial infections which may be influenced by the sulphonamides Certain principles may be laid down which are applicable to acute infections generally —

(a) The nature of the infecting organism should be known
(b) The patient should be recumbent during treatment
(c) It is essential that a high concentration level of the chosen compound be obtained in the blood stream as rapidly as possible and to obtain this the initial or loading dose should on the first few occasions be at least double that subsequently given for maintenance purposes

is insufficient in such circumstances, then a small supplementary quantity of chloroform may be added

In traumatic abdominal surgery, inhalation anæsthesia with nitrous oxide and oxygen supplemented by local infiltration or intercostal nerve block is the method of choice, especially in the presence of shock Alternatively, cyclopropane and oxygen may be used and in cases exhibiting little or no shock gas, oxygen and ether may be necessary because the threshold of the patient's resistance to anæsthesia has remained at its normal level

Dislocations fractures and associated lacerations of the soft tissues are best treated under light general anæsthesia, but it must be sufficient to allow the surgeon to overcome muscular contraction in his manipulations If marked shock is present nitrous oxide and oxygen should be used but where there is only slight shock ether may be added if required Care must be taken during the induction stage lest the patient struggle and convert a simple fracture into a compound one

Burns form a large proportion of the casualties of modern warfare The treatment of extensive burns usually takes some considerable time, and the anæsthesia therefore, must be minimized as much as possible Such cases are generally seriously shocked and show diminished sensibility to pain The only anæsthesia required, if it can be called anæsthesia is light gas and oxygen sleep '

Conclusion—This chapter has dealt mainly with the major problems of anæsthetic administration but the anæsthetist's duties are not restricted to the anæsthetic room and operating theatre He has many minor problems to deal with each quite important in itself, but of which limitation of space prevents discussion

He must arrange the pre-medication for each individual case and find beforehand any special features in the patient's history or state on examination which may influence the choice of anæsthetic, and possibly even the nature and extent of the operation He must be able to give instructions regarding the pre-operative preparation of the unstabilized diabetic or the patient with a fibrillating heart

His versatility must embrace dexterity in applying a tourniquet (and remembering to take it off again), the ability to set up an intravenous drip if called upon to do so, and the complete mechanical knowledge required to look after reducing valves, flowmeters and suction plant

Finally, he is responsible for the proper care of the patient on the return journey to bed and must be ready to advise regarding treatment for anæsthetic sequelæ such as vomiting, respiratory and circulatory depression and chest complications if and when they occur

TECHNIQUE OF ADMINISTRATION

Accuracy and adequacy of dosage—The general scheme for all compounds administered orally is to commence with one two or three loading doses of 2 or more gm at regular intervals followed by 1 gm at the same time interval usually four hours until some response is evident when careful reduction may be begun

Except when sulphanilamide is being administered it is impossible to be sure that sulphonamides given other than by the intravenous route cause adequate concentration of the drug in the blood or other body fluids This is due to the irregularities in absorption from the intestinal tract and also in the rate at which excretion takes place To overcome the effect of these irregularities it is highly desirable to determine from time to time the blood concentration in a given case so that dosage may be suitably adjusted Accurate estimation of blood concentration requires a moderate amount of apparatus and reagents but a useful clinical method (Fig 381) for conducting the tests has been devised by Werner and others[1] The determination of blood levels is of the utmost value in adjusting dosage in patients who are gravely ill or who show poor response to treatment The drugs are rapidly absorbed from the gut and excreted at such a rate that a minimum of four hourly administration is necessary to maintain an effective blood concentration If sulphathiazole is exhibited orally it is necessary to administer the dose two hourly if high concentrations are required (Ravenel and Lesesne Smith)

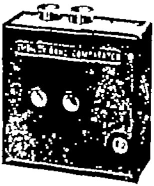

FIG 381
Comparator for clinical estimation of the blood concentration of sulphonamides.

Blood concentration necessary—There is now general agreement amongst clinicians that under ordinary circumstances a blood level of 10 mg per 100 c c is necessary when sulphanilamide is being used and 5 mg or more per 100 c c when sulphapyridine or sulphathiazole is used except in the treatment of severe staphylococcal infections when higher levels appear necessary up to 15 or 20 mg per 100 c c To obtain maximal levels intravenous medication is usually necessary

While in most instances the adequate oral administration of a sulphonamide results in effective blood concentration of the selected compound undue reliance should not be placed on that happening Recent studies by Walker *et al* show that treatment with sulphathiazole does not produce as high concentrations of the drug in the blood as are obtained with sulphapyridine and this applies even when the dosage of sulphathiazole is twice that used for sulphapyridine When sulphathiazole is used there is not the steady rise which occurs in cases adequately treated with sulphapyridine because the drug is rapidly eliminated

Danger of low dosage—Inadequate dosage is certainly more risky than a short intensive course of treatment for underdosage will probably be ineffective and result in prolonged treatment with its attendant risks If low ineffective dosage is increased to more reasonable amounts it is possible

[1] Outfit for performing this test are obtainable from The Tintometer Ltd Milford, Salisbury England.

(*d*) The course of treatment should not exceed ten days duration If there is no response to treatment within three or four days the drug used is unlikely to prove effective, and in this event it may be desirable to change to another

The sulphonamide compounds are active only against certain micro-organisms, and these have the characteristic property of producing acute manifestations There is little evidence that chronic infections due to the same organisms are materially influenced by chemotherapy though the drugs may be of value in acute exacerbations

Micro-organisms on which one or more sulphonamides act in the human subject —

(A) Strong activity

Streptococcus

Lancefield's Group A Streptococcus pyogenes

Diplococcus pneumoniæ
Neisseria gonorrhœæ
,, meningitidis
Klebsiella pneumoniæ (*Bacillus* Friedlanderi)
Pasteurella pestis
Hæmophilus ducreyi
Escherichia coli

(B) Moderate activity

Streptococcus

Lancefield's Group C
Lancefield's Group D (including *Streptococcus* fæcalis)

Streptococcus viridans
Bacillus anthracis
Clostridium tetani
,, Welchii, etc
Staphylococcus aureus
,, albus
Brucella melitensis
,, abortus (possibly)
Hæmophilus influenzæ
Pseudomonas pyocyanea
Proteus vulgaris
Actinomyces

The action of sulphonamides on bacteria *in vivo* is not bactericidal or antiseptic, but is believed to depend on an alteration in their metabolism This effect is to some extent quantitative and the need for high dosage in treating massive bacterial infections must be emphasized The fact that the sulphonamides are antibacterial does not mean that they are antitoxic therefore when appropriate antitoxins are available these should be administered in full doses

their action locally and their action in bacterial inflammation of internal organs such as the lungs While the ravages of the microbes are being checked by chemotherapeutic agents the natural defence and the repair processes of the body still operate and these should be assisted by any appropriate surgical or other methods of treatment

Bacteriology of infected wounds—Wound infections are commonly due to staphylococci streptococci B coli and the anaerobic cocci and bacilli The parts played by Proteus vulgaris and B pyocyaneus in wound infections remain rather obscure Tetanus is rare owing to the growing use of prophylactic inoculation but Dyce Sharp has drawn attention to the efficacy of sulphanilamide as a therapeutic agent even without the administration of antitoxin

The exact nature of an individual infection can only be determined in a laboratory Much assistance is obtainable by the clinician if a direct smear of pus is examined microscopically after the application of a simple stain such as methylene blue

Response to treatment—(*a*) STREPTOCOCCAL INFECTIONS of the beta hæmolytic type either local or spreading serious though they are commonly present no particular difficulty regarding treatment provided this is sufficiently vigorous The low grade and anaerobic streptococci are resistant to treatment but fortunately they are not frequently encountered When they are found in chronic wounds without pronounced slough or pus formation the topical application of sulphathiazole may be successful If hæmolytic streptococci are present in chronic shallow wounds they may often be eliminated by the topical application of sulphanilamide

(*b*) STAPHYLOCOCCAL INFECTIONS are difficult to treat as no chemotherapeutic agent yet discovered has an outstanding activity on the organism It has been found however that sulphapyridine or sulphathiazole given in sufficiently large amounts may at times favourably influence the course of the disease and in septicæmia even alter the characteristic pathology While a blood-stream infection may occasionally be overcome subsequent septic metastases often present grave problems

(*c*) B COLI WOUND INFECTIONS respond well to sulphanilamide but the frequent coexistence of other microbes makes it desirable that compounds with a wider range of action such as sulphapyridine or sulphathiazole should be employed for treatment

(*d*) CLOSTRIDIAL INFECTIONS—The exact place of chemotherapy in the treatment of infections by the clostridia of gas gangrene is still undetermined but it seems an occasion when the combined use of sulphonamides with an appropriate antitoxin of high potency should give the best results The subject is treated in greater detail in Chapter XIII The importance of giving adequate dosage of the chosen compound cannot be overstressed up to 10 gm being necessary during the first twenty four hours treatment in fulminating cases In the less severe infections such high dosage is not necessary if the condition has been treated adequately by surgical or X ray therapy

(*e*) SEPTICÆMIA complicating septic wounds is commonly streptococcal or staphylococcal in origin In some instances the condition may be due to operative interference in infected wounds or to lymphatic spread caused by

that little if any response will be obtained The organisms become drug fast or buried away beyond the reach of any chemotherapeutic remedy This is particularly true in staphylococcal infections Moreover valuable time will have been lost for prompt and energetic treatment is essential for success

Choice of compound to be used—For effective chemotherapy the micro-organism causing the infection must be susceptible to the drug employed There are times when elaborate investigations are not possible and it may be found there is not the expected response to treatment in such circumstances it is desirable to change the compound to another which is considered likely to be active By far the best procedure in difficult cases is to test the sensitivity of the isolated organisms to the available compounds, using the slide-cell technique devised by Fleming

Intravenous therapy—As a supplement to sulphonamides administered orally a few initial intravenous doses of a soluble compound are useful in the treatment of severe infections Under certain circumstances, as for example in septicæmia it may be desirable to rely entirely on continuous intravenous therapy For this purpose the appropriate amount of soluble drug is dissolved in normal saline or 5 per cent dextrose solution between 2,000 and 3 000 c c being given in twenty-four hours Blood concentration levels are adjusted by adding more drug or by increasing the rate of flow In anæmic patients or those requiring transfusion for some other reason it is possible to add the soluble compound to the blood but care must be taken to use fresh and not the stored variety as fibrin may be precipitated

The intramuscular injection of soluble neutral compounds or preparations of sulphanilamide is a handy procedure and does not cause local reactions The position is different when the alkaline sodium salts of sulphapyridine or sulphathiazole are used in this manner as local muscle necrosis may be caused This damage may in some measure be avoided by ensuring that the injection is given deeply into the gluteal muscles and that no solution is permitted to escape along the needle track It is the severely ill patient who requires parenteral therapy and such cases usually have some degree of peripheral circulatory collapse It is unlikely, therefore, that intramuscular injections or drugs by hypodermoclysis will reach the general circulation as effectively as when the same compounds are given intravenously

Rectal administration of sulphonamides—The rectal administration of sulphonamides may be a useful alternative to continuous intravenous therapy A saturated solution of sulphanilamide in normal saline or a 1 per cent solution of sodium sulphapyridine is commonly employed, a total dosage of 7 to 10 gm being given in twenty-four hours To be effective the solution should be given in a continuous drip at a rate of about 60 c c per hour, but care must be exercised to see that enough is absorbed to ensure a therapeutic level in the blood stream Regular examination of the blood concentration level must therefore be carried out

SULPHONAMIDES IN SURGERY

To understand the part played by sulphonamides in the treatment of sepsis it must be fully realized that these drugs act on some of the micro-organisms found in wounds, and there is no difference in principle between

concentrations If it is possible to ensure an adequate local concentration of a drug by the oral or some other route then such should be attempted and additional local treatment given if possible Local application is rarely as effective in treating acute wound sepsis as adequate general sulphonamide treatment In chronic wound sepsis local application is always worth a trial as general administration is usually ineffective or even harmful

Before local application is attempted it is valuable to have an idea of the bacteriology of the wound and it is also of fundamental importance to remove as much detritus as possible for albuminous material inhibits the antibacterial action of sulphonamides It will be readily understood how limited must be the local activity possessed by a sparingly soluble compound such as sulphapyridine (1 3 000) Sulphanilamide which is 1 per cent soluble possesses only a limited range of antibacterial activity principally against hæmolytic streptococci Because hæmolytic streptococci are so frequently present in surface traumatic wounds or burns sulphanilamide may be usefully employed in their treatment After cleaning the wound with normal saline solution the powdered drug is applied with an insufflator or by similar means, or alternatively in an ointment base Various bases have been recommended and in the local treatment of burns such preparations have obvious merits

An important use of sulphanilamide is its local application to wounds prior to and at the time of skin grafting operations The incidence of local reactions and failures caused by streptococcal infections has been strikingly diminished (Mowlem)

The local use of the soluble derivative of sulphanilamide Soluseptasine and the sodium salt of sulphacetamide Albucid soluble is attracting attention but both these drugs have a restricted range of activity The alkalinity of the freely soluble sodium salts of the more active drugs sulphapyridine and sulphathiazole restricts their local use The local treatment of chronic staphylococcal infections is difficult but occasional success has followed the application of sulphathiazole which is soluble 1 2 500 (Martindale)

Provided a reputable sulphonamide preparation is used there is no necessity to sterilize it before application to an open wound Herrell and Brown who have investigated the matter state that they have never seen and do not know of any incident in which the development of infection due to spore forming organisms could be attributed to the introduction of any of these drugs into an infected wound Should sterilization of any sulphonamide preparation be desired this may be done in a vacuum autoclave

PROPHYLACTIC USE OF SULPHONAMIDES

The value of sulphonamides as an adjuvant to surgical operations performed in the presence of sepsis is unquestionable when they are given in amounts sufficient to obtain a bacteriostatic concentration in the blood

The prophylactic implantation of as much as 15 gm of sulphanilamide into wounds is often successful but surgical advance is rapid and the credit for results obtained may be partly due to other procedures employed It must always be remembered that sulphanilamide the drug most commonly used has only a limited range of activity

The local use of sparingly soluble compounds having a wider range of

movement of muscles round local sepsis. The prophylactic value of immobilization against the spread of sepsis has been emphasized by recent experiments carried out by Trueta *et al.* It is impossible to detail the exact treatment necessary for each case because the cause and the circumstances differ so much from case to case. The best approach is to deal suitably with the local sepsis by surgical or other means and at the same time treat the septicæmia by chemotherapy combined with any sera or vaccines considered desirable. In acute streptococcal diseases sulphanilamide, or benzyl sulphanilamide, alone or with a soluble derivative of sulphanilamide are the most satisfactory compounds, and the incidence of side effects will be less than if some of the other antistreptococcal agents are employed. In subacute streptococcal diseases the use of sulphapyridine or sulphathiazole is indicated, as they are the most active compounds yet available for the purpose. As previously mentioned, staphylococcal cases do not respond well to treatment. Success has however sometimes followed the administration of sodium sulphapyridine or sodium sulphathiazole dissolved in normal saline, or 5 per cent. dextrose, continuously by the intravenous route. Up to 15 gm. sulphapyridine and 30 gm. of sulphathiazole may be administered throughout the twenty-four hours and continued at this rate for three or four days, suitable adjustments in dosage being made by observation on the blood concentration levels attained (see p. 493).

Treatment of acute wound infections—Experience shows that local wound infections are most influenced by chemotherapeutic agents when the process is of an acute character, that is, when the patient is febrile and shows signs of general reaction. Whatever sulphonamide is chosen for treatment the initial dose should not be less than 2 gm. given four-hourly for two or three doses, followed by not less than 1 gm. at four-hourly intervals for two or more days before tapering is commenced. In very ill patients an initial dose up to 5 gm. may be given and followed by two or three subsequent doses of 2 or 3 gm. A total dose of 20 to 30 gm. is usually sufficient, but it may be exceeded provided regular examinations are made to observe any signs of leucopenia or other blood dyscrasia.

Treatment of chronic wound sepsis—For various reasons chronic wound sepsis does not respond well to sulphonamides given in the ordinary way. Their administration may indeed be fraught with danger, firstly, because there is a temptation to continue dosage for too long a period, and secondly, because patients with chronic sepsis are frequently subject to a degree of anæmia which may be accentuated by sulphonamides, unless special precautions are taken. It is in this type of chronic case that the local application of sulphanilamide may be useful, particularly when the organism is a hæmolytic streptococcus. The local effect of other compounds which are sparingly soluble is still being investigated.

The basis of success following use of the drugs in this way is their ability to provide a bacteriostatic concentration in tissues adjacent to the infected area. To use the compounds in purulent wounds is no more likely to be successful than if ordinary antiseptics are employed, but occasional successes have been reported. This is possibly due to the bactericidal effect of sulphonamides when high concentrations are present, for unlike the ordinary antiseptics these drugs do not cause local tissue damage even in high

staphylococcal lung infections which follow some epidemics of influenza (Melton)

There is increasing evidence that sulphonamides properly administered may relieve the bacterial complications of the common cold To avoid the recumbency necessitated by oral therapy the suggestion has been advanced that relief may be obtained by spraying the nasal meati with a solution of soluseptasine but confirmation of this work is necessary

(*d*) **Meningitis**—The clinical types of acute meningococcal infection present differences in the degree of meningeal involvement but treatment of all types is similar both with regard to the compounds used and their method of administration Sulphanilamide or sulphapyridine should be given in the dosage advocated by Banks which is a daily total of 9 gm of sulphanilamide given at regular four hourly intervals day and night for the first two or three days the initial two doses being 2 gm each and the subsequent ones 1 5 gm each If there is clinical improvement dosage should gradually be reduced at the end of about three days and treatment completed in not more than seven to nine days Clinical experience suggests that sulphapyridine is a more effective drug than sulphanilamide against meningococci and that 9 gm on the first 8 gm on the second and 7 gm on the third day are adequate before material reduction in the dose is begun

If patients prove intolerant to sulphapyridine sulphanilamide or sulpha thiazole must be substituted but in severe infections neither of these compounds seems as active as sulphapyridine

In unconscious patients or those with circulatory collapse when oral therapy is impossible the parenteral administration of sodium sulphapyridine solution should be adopted preferably by the intravenous route 1 gm being dissolved in 20 c c of normal saline before injection Deep intra muscular injection of not more than 3 c c of 33⅓ per cent solution of sodium sulphapyridine may be attempted but absorption into the general circulation is often slow and as mentioned earlier in this chapter severe local reactions can occur

Following the diagnostic lumbar puncture it is frequently unnecessary to repeat this operation There should be no hesitation in doing so should pressure symptoms be urgent or if response to treatment appears somewhat tardy The state of the cerebrospinal fluid can then be observed and the concentration of the compound estimated it should never be materially below 5 mg per 100 c c in the acute phase It may be found in certain cases that despite intensive dosage with sulphapyridine and the attainment of a satisfactory concentration in the blood there is difficulty in achieving an adequate level in the cerebrospinal fluid It seems that such cases are the subject of severe choroidal damage which interferes with the secretion of sulphapyridine (Whitelaw and Thrower) The intrathecal injection of sulphonamides should never be attempted in these or any other case as serious damage to spinal nerves will result In these severely ill patients much may be done by forcing fluids even by the intravenous route in which case the sodium salt of sulphapyridine may be added to the infusion.

Specific serum treatment may be desirable as an adjuvant to chemo therapy in certain cases but there is increasing evidence that success is likely with sulphonamides alone provided they are administered with circumspection

activity than sulphanilamide does not seem justifiable when these may be given orally or by other means, with every prospect of their being absorbed. If a soluble sulphonamide is placed in a wound its effect is, of course, transient, and it is essential to continue with oral therapy.

Micro-organisms as a class thrive in the presence of damaged tissue. While surgical treatment aims at the total removal of such tissues, this is occasionally incomplete and local infection may follow. In such cases prophylactic chemotherapy is highly desirable. Whatever scheme of dosage is adopted it must be vigorous, because the organisms present may become resistant to the compound used and dangerously high dosage is then necessary to master the infection.

Mitchell *et al.* have fully described the scope and limitations of sulphonamides used under field conditions in the Libyan campaign. They confirm the importance of adequate regular medication and the need for scrupulous attention to general surgical principles as well.

SULPHONAMIDES IN GENERAL MEDICINE

Surgeons practising in the Services may have to treat general diseases where in some respects the action of sulphonamides is more striking than in purely surgical conditions.

(*a*) **Erysipelas** and other similar local or spreading streptococcal diseases respond well to sulphanilamide or benzylsulphanilamide given in standard dosage, supplemented on the first few occasions if desired with an injection of a soluble sulphonamide.

(*b*) **Pneumococcal and streptococcal pneumonia**—Severely ill patients or those with the disease well established should receive a minimum of 2 gm. of sulphapyridine or sulphathiazole as an initial dose followed by a further 2 gm. in four hours' time and even a third if necessary. Subsequently 1 gm. should be given at four-hourly intervals for about thirty-six hours except during sleep, adjustments being made for this. Sulphapyridine seems to be more active in the treatment of pneumococcal pneumonia than sulphathiazole, but the latter has the advantage of being better tolerated. After the initial intensive treatment there will commonly be clinical evidence of response, and the dosage of 1 gm. four-hourly should be maintained for a further twelve hours. Thereafter the dosage may be reduced by administration of 0.5 gm. four-hourly for another twenty-four or thirty-six hours, finally giving 0.5 gm. eight-hourly for two days. A total dosage of 20 to 25 gm. is adequate in most cases. Should circumstances prevent oral therapy, then a parenteral preparation should be used for the first few doses till oral therapy is resumed. In moderately severe cases, after an initial dose of 2 gm. four-hourly administration of 1 gm. may be commenced.

(*c*) **Non-pneumococcal respiratory infections**—The sulphonamide drugs have a distinct place in the treatment of acute respiratory complications associated with such diseases as epidemic influenza and certain common colds which prove such a scourge in closed communities. With one exception (psittacosis) the sulphonamides appear to have no action on the viruses which affect the respiratory tract. When complications due to secondary bacterial infections occur these may be successfully treated with sulphapyridine or sulphathiazole, the latter being particularly valuable in the

staphylococcal lung infections which follow some epidemics of influenza (Melton)

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Specific serum treatment may be desirable as an adjuvant to chemotherapy in certain cases but there is increasing evidence that success is likely with sulphonamides alone provided they are administered with circumspection

(e) **Meningococcal septicæmia**—This condition is being increasingly recognized as a clinical form of meningococcal infection, but the diagnosis depends for certainty on a positive blood culture. The response to treatment with sulphapyridine is dramatic (Dickson).

(*f*) **Gonorrhœa**—Sulphanilamide has been generally superseded by sulphapyridine or sulphathiazole, the latter compound enjoying increasing popularity because it is well tolerated. There is still considerable doubt among clinicians about the daily dosage necessary for success and the number of days over which treatment should extend. Some believe in an intensive course lasting for three or four days. After the initial dose of 4 gm. and a second dose of 2 gm. the patient receives 1 gm. at four-hourly intervals throughout the waking day, *i.e.*, four or five doses each of 1 gm. in the course of twenty-four hours, until a total of 19 gm. has been administered. On the first day many patients are nauseated and ill, but thereafter only a few are upset.

A more common practice is to use a moderate dosage, giving 4 gm. (1 gm. four times a day) on the first day, and continuing with 3 gm. (1, 0.5, 1 gm.) daily until 15 to 20 gm. have been given. Thereafter some terminate administration altogether, while others continue on a reduced daily dosage of 2 or 1.5 gm. for a week. Local treatment is sometimes given with these dosage schemes. A small number of clinicians give 0.5 gm. three or four times a day for two or three weeks, combining this with urethral irrigation.

(*g*) **Plague**—The successful treatment of B. pestis infections with sulphathiazole, originally described by Sokhey and his co-workers, may prove most valuable in view of military developments in the East. The dosage he recommends is 1 gm. on admission to hospital and 0.5 gm. every four hours thereafter for a maximum period of seven days, but more intensive therapy may well be found desirable.

(*h*) **Bacillary dysentery**—There is increasing evidence that sulphonamides are effective in the treatment of the acute phase of B. dysentery, and the use of sulphanilylguanidine has been advocated for this purpose. Studies by Reitler and Marberg show that equally good results may be obtained by the use of sulphapyridine (1 gm. t.d.s. for two or three days) or sulphathiazole, and the general availability of the former drug in particular is of administrative advantage under field conditions.

GENERAL MEASURES

While the place of sulphonamides in the treatment of certain microbic infections is fully established, there is no justification for abandoning various adjuvants to treatment of a general or special nature, the value of which is fully established in practice. Diseases of the kind treated by chemotherapy still develop their local and general tissue reactions although the causal organism itself may be controlled, so the place in treatment of rest, diet, adequate fluids and sera of different kinds remains as important as ever. Dietetic restrictions, particularly as regards sulphur, have been imposed on patients undergoing chemotherapy with sulphonamides, but against the possible occurrence of the rare condition sulphæmoglobinæmia, must be offset the practical difficulties of the material departure from standard diets, and the fact that in actual experience no harm results.

COMPLICATIONS

The recognized complications of sulphonamide therapy are varied but fortunately rare unless the compounds are misused. For the most part complications can be avoided by attention to technique, while the value of recumbency during treatment cannot be overstressed. Nausea and vomiting are often troublesome but may be overcome by varying the manner in which the particular drug is exhibited or by changing to another if such be available. The administration of the amide of nicotinic acid has proved valuable in some clinics in overcoming complications of sulphonamides. Blood dyscrasias can be recognized by periodic white blood counts and haemoglobin estimations which must be carried out if treatment is at all prolonged. Should a blood change develop then sulphonamide treatment must be immediately suspended and vigorous counter measures undertaken. Repeated blood transfusions are given and supplemented if necessary by injections of pentnucleotide, though severe reactions have been reported after its use.

Cyanosis is commonly observed during treatment with any sulphonamide drug, particularly sulphanilamide. It is generally due to methaemoglobinaemia but is no occasion for alarm, and treatment should not be suspended solely for this. Relief may be obtained by giving 0.3 gm. methylene blue orally three times a day or 0.1 gm. intravenously.

Drug fever is a complication of treatment which is important, for it often appears towards the end of treatment and simulates a relapse in the disease. The temptation to continue with sulphonamides must be resisted in such circumstances and the drug suspended for a while until the real significance of the rise in temperature can be recognized. The increasing use of sulphathiazole in clinical medicine has presented an opportunity for observing the somewhat unusual complications peculiar to this drug, namely conjunctival injection and the development of a rash which differs from the diffuse pleomorphic rash well recognized with other drugs in being nodular in character and resembling erythema nodosum.

Haematuria may be avoided to a large extent by always ensuring a high fluid intake (Laird).

For a full account of the etiology and management of cases showing ill effects from sulphonamide treatment special articles on the subject should be consulted. The comparative rarity of complications and the outstanding value of the drugs when properly used continue to give them a unique position in everyday practice.

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SECTION X

BURNS AND FROST-BITE

CHAPTER L

BURNS AND THEIR TREATMENT

BURNS have resulted from incendiary warfare since the earliest times and may be due to a variety of causes. Petrol, oil, superheated steam, cordite and the flash from high-explosive and incendiary bombs are the common cause of burns as seen in the present war.

During the Great War of 1914-18 the commonest cause of burns in the navy was cordite, many cases being caused by the back flash from the gun turret down the ammunition shaft to the store; this cause is almost eliminated now owing to the new construction of the ammunition shaft and to the fact that all men working in the turret wear anti-flash gear (Fig 382).

FIG 382

Anti-flash gear as issued to the Royal Navy. The gas mask is only worn when there is a danger of a gas attack.

In the present war, with such a preponderance of aerial bombardment both on land and sea, petrol and oil burns (see p. 523) are common, while those due to electricity have increased in frequency. Quite often when a ship has been bombed it blows up and the oil tanks burst and the sea for miles round is covered with boiling oil; numbers of men swimming in the sea about the destroyed ship will receive burns of the head, face, arms and hands. The explosion of petrol dumps and aeroplane crashes constitute a common form of petrol burn, while the incendiary bomb, by causing multiple fires, is responsible for a number of civilian burn casualties.

Amongst the rare causes of burns are those due to the explosion of special bombs which contain phosphorus and other special material; burns due to these substances require particular treatment or else they become more extensive and deeper.

Phosgene and mustard-gas burns must be recognized and promptly treated if a successful issue is to be obtained.

As in the last war so in this one, burns form a high percentage of the casualties admitted to both service and civil hospitals. In the navy the

percentage has been very high owing to the constant bombing of every variety of ship.

During 1914-18 the first-aid dressing for burns consisted of gauze soaked in a weak solution of picric acid, and although it did coagulate the tissues and so to a certain extent prevented absorption of toxic products, yet the removal of this dressing often caused a first-degree burn to become a second-degree one or converted a second-degree burn into one of the third degree. I went to some pains to point this out to the profession, and to-day there are some excellent forms of treatment which give universally good results.

It should be the aim of every medical man to treat cases of burns in such a way that a minimum amount of scar tissue is produced in the healing processes. The mortality rate due to burns varies with the area of the burn; it is the extent of the burn rather than the depth which endangers life. If more than a quarter of the surface area of the body is burnt there is a serious threat to life.

CLASSIFICATION OF BURNS

The large number of burns which have been treated both in the forces and in civilian hospitals since the present conflict started has necessitated a more definite and practical classification of burns than that which was devised by Dupuytren.

Although the extent of a burn is important, there is little difficulty in estimating the volume of skin involved in the injury. Yet it is the depth or degree of the burn which is really more important from the practical treatment standpoint. Therefore it is more convenient to describe the depth of skin damage, and so two types are recognized.

1. Burns involving partial skin loss, including first and second degree burns of Dupuytren's classification.

2. Burns causing total skin loss, including third and even fourth degree burns of Dupuytren. More often than not war burns consist of both types; there will be areas of partial skin loss and others in which there is total skin loss.

While it may be difficult to assess the actual depth of damage in burns an attempt should always be made, because unless this is done an accurate assessment of treatment cannot be obtained. Where there is total skin loss fat may at times be seen in such areas, and this may help in the differentiation of the two types of burn.

It is impossible to treat war burns in a sound practical manner unless we have a correct idea of the clinical course of these injuries. Again, much of our knowledge relating to the pathological processes which take place in burnt patients comes from an examination of fatal cases.

It may be said that the fatal results from burns fall into four categories:—

1. **Primary shock**—This arises immediately after the injury and may be likened to a condition resembling a fainting or syncopal attack. This form of shock is rarely seen in the men of the fighting services but may be seen in patients removed from burning houses, and it may well be that the psychological factor plays a part in its production.

The clinical picture is well known: there are signs of lowered blood

pressure the pulse is usually fast feeble and of poor volume The patient is cold and often sweating while a definite pallor is present Fear often increases the shock and the patient develops an anxious expression

This condition is not likely to be serious and responds well to treatment by the application of warmth and the relief of pain by a hypodermic injection of morphia Warmth can be readily applied by an electric blanket or hot water bottles Electric blankets have proved invaluable in naval hospitals where a large number of burn *cases have been treated.*

The patient should be reassured and here the importance of the nursing profession comes to the fore A cheerful tactful nurse may do much to combat the anxiety of the patient who is suffering from a multitude of fears whether he is going to die lose his sight be deformed or be invalided out of the service in which he is serving Good nursing is essential in the treatment of shock. However primary initial or immediate shock carries a small mortality and accounts at most for only 2 or 3 per cent of the deaths from burns and scalds Statistics however in war time are apt to be fallacious because quite frequently burn casualties may also be suffering from fractures or war wounds which in themselves will increase the mortality figures Repeated examinations have failed to reveal any abnormality in the blood chemistry

2 **Secondary shock**—This is responsible for about 80 per cent of deaths from burns and therefore calls for early recognition and prompt and adequate treatment Secondary shock or collapse as some prefer to call it develops rapidly and manifests itself within two hours of the injury

The cause of secondary shock although debated in the past has now been placed on a sound basis It is due partly to the tremendous destruction of protein and absorption of histamine bodies from the damaged tissues and partly to the great loss of plasma from the burnt surface The plasma escapes from the blood stream on to the surface and into the tissue spaces of the whole area involved in the burn and this mechanism continues for hours unless stopped by proper treatment Although some fluid with its valuable *protein is actually lost externally the amount is quite small* compared with that which accumulates in the tissues It is in reality a fluid imbalance due to a shift of fluid rather than an external loss It is important to realize this because the fluid lost from the blood vessels to the tissues can best be regained by replacing the lost plasma protein If plasma is given intravenously it raises the plasma osmotic pressure to a value sufficient to restore and maintain the normal distribution of fluid between the intravascular and interstitial compartments Whole blood transfusion is contraindicated because it produces corpuscular concentration and the capillaries become blocked with a huge excess of red blood corpuscles Intravenous normal saline or sterile water are also contraindicated because the former will only increase the œdema while the latter may result in a hazardous lowering of the extracellular electrolytic concentration producing water intoxication By animal experiments it has been shown that this plasma loss is greatest in third-degree burns and amounts to over 70 per cent of the total blood volume in cases where one-sixth of the body surface has been burnt

The result of this plasma loss is a definite fall in the blood pressure Tissue fluids deficient in protein pass into the blood vessels in an attempt

to maintain the volume of plasma in circulation however, this results in a lowering of the concentration of protein in the plasma There is a high urinary output of nitrogen due to the destruction of protein

As the diminution of the blood volume is due to loss of plasma there will be a concentration of corpuscles, especially in the peripheral capillaries. hence, unless treatment is instituted circulatory failure will cause the death of the patient

3 **Toxæmia**—This is a condition of septic intoxication which tends to occur from forty-eight hours to ten days after the injury, and is the result of absorption of injured cells and tissue in the region of the burn This process of septic absorption as it progresses floods the circulation with its products which when they reach the liver cause some necrosis of the liver cells Should some bacterial invasion into the burnt area also take place the degree of toxæmia becomes much more marked The clinical picture is well known and consists of a distressed and irritable patient with a high temperature, rapid pulse and complaining of headache and loss of appetite By the time such symptoms have developed the actual burnt area is obviously septic and exudes sero-pus This state of affairs should not be seen at the present day for it can be prevented by prompt and adequate treatment, but in warfare it often happens that burn cases do not receive prompt treatment and therefore a certain number exhibit acute toxæmia when admitted to hospital or hospital ship

Once the toxæmia has gained a foothold it is difficult to eradicate, and if sepsis is well marked septicæmia and pyæmia may supervene Duodenal ulceration is a rare complication of infected burns and it was not met with in the navy in the Great War when over a thousand cases of grossly infected burns were treated in the naval hospitals and hospital ships

4 **Scarring**—This is really a complication which should for the most part be preventable It should never occur in burns with partial skin loss but it will occur in extensive total skin-loss burns unless they are skin-grafted immediately the burnt area is covered by granulation tissue If burns are allowed to become infected then, there is a danger of scar-tissue formation with resulting scarring

Scarring may cause grave depression on the part of the patient and may lead to suicide while in some cases carcinoma may develop at the site of the scar Treves and Pack of New York reported a series of thirty-four such cases in 1930

TREATMENT OF WAR BURNS

The first and foremost aim in the treatment of burns is to save life Now that the pathology of burns is on a sound basis it is quite easy to lay down definite principles of treatment and so obtain uniformly good results and a marked lowering of the mortality rate

The general treatment consists in combating shock preventing acute toxæmia and sepsis and eliminating scarring Quite a number of burns are preventable by the use of anti-flash protective gear especially in gun crews in the navy The great majority of war burns involve the face and hands and in facial burns the ears are often a great problem as the thin skin over the pinna is destroyed leaving the exposed denuded

cartilage which frequently becomes infected. Anti-flash gear (see Fig. 382) consists of long asbestos gloves and an asbestos helmet which covers the head, ears, neck and chin, leaving an aperture for the eyes, nose and mouth. Considering the very large proportion of burns of the hands and face in the Royal Navy, it has been thought advisable to issue an eye-shield of cellulose acetate and a small mask made of aertex material impregnated with heat-resisting solution. This mask covers the nose and lower part of the face (Fig. 383) and is worn by all men who are exposed to bombing and all gun crews. This protection is worn over the anti-flash gear when the Service respirator is not used. It is very simple, of small cost and can be easily stowed away inside a steel helmet.

Treatment of shock—Probably hæmoconcentration is the earliest clinical sign of shock. It is a good thing that this manifestation is easily detected and assessed.

A patient in a state of shock from war burns is in need of six things: (1) morphia, (2) warmth, (3) fluid to balance the great plasma loss, (4) reassurance, (5) oxygen and (6) rest.

FIG. 383

New mask issued to the Royal Navy for protection of the face.

Morphine should be administered as soon as possible, $\frac{1}{4}$ and/or $\frac{1}{2}$ gr. if the pain is severe. There seems to be a totally unwarranted fear among doctors of overdosage of morphine in the treatment of shock. On many occasions badly burnt pilots have received 2 gr. of morphine in the same number of hours, and there cannot be the slightest doubt that this treatment played an important part in saving their lives. *Morphine will never kill a patient who is suffering severe pain.*

It cannot be emphasized too often that in war burns there is a much greater danger to patients from insufficient than from an excessive dosage of morphine.

The actual amount of morphine administered will depend on the condition of the patient, but if pain is severe it may be necessary in some cases to give an injection at hourly or half-hourly intervals until the pain is relieved.

Warmth can be obtained by hot blankets, electric blankets, heated shock cradles, hot water bottles, hot sweetened drinks and other measures according to the circumstances. Wherever possible the temperature of the first-aid post, resuscitation ward or other place where the injured patients are treated should be 100° F. or even higher.

Fluids should be administered by the mouth if possible, but this in itself is often not sufficient to replace the great plasma loss from the blood vessels, therefore intravenous infusion of plasma should be given (see Chapter VII).

Although there are many ways in which to estimate the amount of plasma required in cases of burn shock, it is essential that whatever method is used must be simple and easily and quickly performed. Harkins' method has proved very valuable where many war burns have had to be treated at the same time.

It consists in giving 100 c c of plasma for every point the hæmatocrit is above the normal of 45 This method applies to adults and involves the assumption that the patient's hæmatocrit reading before the injury was normal For children the amount of plasma is calculated proportionately according to body-weight, with the average adult weight of 70 kgm If the plasma protein is below normal, this method gives too low a value For such a case an additional 25 per cent of the calculated amount of plasma should be added for every gramme the protein level is below 6 0 gm per 100 c c

An actual case will illustrate this method

Case 2105, 1941 Able seaman burnt from bomb flash Mixed burns of face, chest and legs (28 per cent of body surface)

> Initial hæmatocrit reading after burn=58
> Initial plasma protein=6 51 gm

Hæmatocrit reading is 13 points above normal of 45 and plasma protein is above 6 gm , therefore 1,300 c c plasma is required and was given with a very satisfactory result

Whole blood transfusion is not indicated in the treatment of shock unassociated with hæmorrhage, because it only hampers the patient by increasing the hæmoconcentration which is already present (*vide* Chapter V)

Should plasma not be available the best substitute is a 6 per cent gum saline solution

Adrenal cortical extract may be given intravenously if shock is severe, but it must be remembered that this mode of therapy is still in the experimental stage It has been used with advantage in the Royal Navy Two cubic centimetres of cortin are given intravenously and this is repeated at four-hourly intervals during the period of shock

Oxygen is invaluable in all cases of extensive and severe burns Nasal catheters can be used in the milder cases, and oxygen tents or helmet respirators in cases where the face and nose are burnt

As a large number of war burns involve the face, the helmet respirator connected to an oxygen cylinder has proved invaluable, a high concentration of oxygen has been made available to the patient by this means

For extreme cases the B L B mask (see Chapter IV) should be utilized, as it is capable of giving 90 per cent oxygen

It has been found that elevation of the feet is a useful temporary emergency measure in the treatment of shock, but the elevation must not be excessive or too prolonged

Toxæmia and sepsis are the bugbear of war burns and should be prevented by prompt coagulation of the burnt area This fact has been forgotten or has never been realized by some medical men The thousands of burns which have been treated in the fighting and civilian medical services have proved the real value of the coagulation therapy There is no contra-indication to its use

First-aid treatment should be directed to the cure of the initial shock and the prevention of collapse Pain is relieved by an injection of morphia, and the patient should be reassured that he will be all right, because in so many cases there is an element of fear A cheerful word here and there

works marvels when dealing with forty or fifty badly burnt cases The surgeon must have some knowledge of psychology so that he can rapidly distinguish the patients who require cheering up from those who can get along well without it

A hot sweetened drink should be given if possible and warmth applied until the burnt area can be dealt with A shock cage is very useful but it must not be too hot for excessive heat may be harmful to a shocked patient

When the patient has come under the influence of morphia it is necessary to expose the burnt areas in order that coagulation may be effected and loss of plasma from and into the burnt tissues restricted

The clothing is removed and all charred remains of clothing are picked off the burn with the forceps and any blisters opened with scissors The burnt area is covered with gentian violet jelly (1 per cent) or triofax jelly which is a triple dye jelly (gentian violet 1 per cent brilliant green 0 1 per cent euflavine 0 1 per cent in a water soluble base) The application should be liberal it is painless causes coagulation and produces a soft pliable tan These jellies are put up in 4-oz. tubes which are suitable for use in a ship tank aircraft or first aid post (Fig 384) There are other jelly preparations such as tannax tannafax and dettol burn jelly but they are not so efficient as those containing the aniline dyes

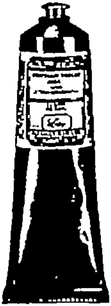


Fig 384

Tube of gentian violet jelly as supplied to the Services. Easy to handle cannot get upset and if immersed in oil or débris can be easily cleaned.

The Heggies working at a naval hospital in Aberdeen have found the following jelly satisfactory It is soothing antiseptic and analgesic —

Tannic acid		20·0 per cent
Proflavine sulphate		0 1
Procaine		2·0
Pulv tragacanthæ co		2 0
Glycerine		10·0
Distilled water	ad	100·0

Foille can be used as a first-aid dressing and gives good results in burns of minor degree Foille is a stabilized water in-oil emulsion and is an excellent dressing for burns of the face Its constituents are as follows —

Alcohol	1 4 per cent
Benzocaine	1 3
Oxyquinoline base	0 2
Phenol	2 8
Calcium soap	0 30
Calcium iodide	0 25
Potassium iodide	0 14
Calcium thiosulphate	0·02

The action of foille over the burnt areas is to form a soft but moist yellowish-brown incrustation The calcium soap content contributes to this coagulated exudate and serves to provide a protective covering under which epithelialization can take place

Burns involving the eyes and eyelids should be treated with castor oil and cocaine drops The patient should be transported to a hospital as soon as possible Under war conditions it may be several days before Service burn casualties can be transported to hospital, but civilian cases are usually removed under three hours unless an intensive air raid is in progress

Hospital treatment—The majority of war burns will have received first-aid treatment before arriving at hospital It makes little difference, however, because each and every case of extensive or severe burns requires a general anæsthetic and a complete surgical cleansing Burn cases should, if possible, be treated in special wards with special nurses to attend them Sepsis is the most serious complication, it must be eliminated from the onset and cross-infection from one patient to another avoided Special wards are therefore necessary, and medical officers and nurses must be surgically clean and wear sterile masks while dressing burn cases in the wards A general anæsthetic allows the surgeon to make a very thorough inspection of the burnt area and to examine the patient for other injuries It must always be remembered, however, that in some cases burns may be complicated by blast injury to the lungs and therefore a general inhalation anæsthetic may be dangerous For such cases avertin anæsthesia has proved most valuable and is not contraindicated in the presence of shock

In the majority of cases, however, gas and oxygen anæsthesia is the best and it does not cause cyanosis

All measures to combat or treat shock having been undertaken, a very thorough cleansing of the whole of the burnt area is undertaken while the patient is under general anæsthesia in the operating theatre Blood-pressure readings are taken and the blood examined for hæmoconcentration Strict aseptic precautions should be observed by everybody in the theatre All loose and blistered skin should be cut away and the edges of the burnt area carefully excised and the whole area covered with a saline gauze pack It is most important that no antiseptic lotion or ethereal soaps be applied to the denuded area After the saline pack has been applied for five minutes the area is swabbed or sprayed over with a 1 per cent aqueous solution of gentian violet or an aqueous solution of a triple aniline dye (gentian violet 1 400, brilliant green 1 400, flavine 1 1,000) The whole area is then completely dried by means of a current of hot air from an electric hair dryer

Following this a 5 per cent solution of tannic acid is washed over the area and dried This in turn is followed by a wash of 10 per cent silver nitrate A firm coagulum forms over the whole of the burnt area If the blood examination indicates a plasma transfusion this is given while the patient is still in the operating theatre The patient is returned to bed and nursed under a shock cradle, no dressings whatsoever being applied over the tan

As a rule the coagulum should remain adherent from fourteen to sixteen days Any cracks which appear in the coagulum are likely places for the

entrance of bacteria and therefore applications of gentian violet should be made It is very important to inspect the tanned area every day for cracks in the coagulum or signs of moisture or exudate around the edge of the tan These must be promptly treated with a solution of gentian violet A lack of observation leads to much disappointment and the occurrence of sepsis

For those cases in which sepsis is well established under the tan the only course to adopt is to remove the tan under an anæsthetic and cover the whole area with saline packs which must be kept constantly moist

There is still too much complacency in the treatment of burns much too much being left to the nurses and orderlies which is a great pity Should the tanned area become soiled with urine or fæces it should be cleansed with some 10 per cent dettol and then dried after which a 1 per cent solution of gentian violet is applied

For large extensive burns involving the extremities and the trunk a complete saline bath is the ideal treatment The patient is slung in a large bath of saline which is kept at body temperature by means of an electric rheostat and the saline is constantly changed by a mechanical device These baths are only fitted to a few Service hospitals but they do save the lives of patients with very extensive burns The patients find the saline baths very soothing the heat of the body is conserved and any toxic products are washed away The patients can tolerate four or five hours in the bath and this period is increased each day When not in the bath the burnt areas are covered with tulle gras (see Chapter XV) This is a soothing dressing which does not stick to the burnt area and floats off when the patient has the next bath The patient is nursed in a reversible spinal bed such as the Hey Groves model Such a reversible bed allows the patient to be turned over for the application of the tulle gras Sulphanilamide powder may be dusted over the area prior to the application of the tulle gras

Oral administration of sulphanilamide is not necessary unless the burnt area is septic because the patient requires a high protein diet with plenty of eggs to replace his lost plasma protein Sulphur is also indicated because it must be remembered that about two thirds of the body sulphur is in the skin and eggs form the best method of replacing this loss Sulphanilamide prohibits the inclusion of eggs in the diet moreover it frequently makes the patient vomit thus still further reducing the fluids of the body Tonics should be prescribed as soon as the patient will tolerate them Iron and vitamins are indicated, and a form of tonic found especially useful is metatone a compound made by Parke Davis & Co It is very important to advocate a high protein diet in all bad burn cases not only to replace the loss of plasma protein but also to cover the tremendous loss of nitrogen in the urine

Burns involving partial skin loss will heal well under the tan and an excellent result can always be expected if sepsis is eliminated

Burns involving total skin loss can only heal by granulation and by a process of ingrowths of epithelium from the periphery of the burnt area Such ingrowths if large will always give rise to very thin skin which is liable to crack fissure and to form keloid scars (Figs 385 and 386) As soon as granulations have appeared skin grafting should be undertaken *It is only by the early use of skin grafting that contractures can be prevented in extensive total skin loss burn cases* As soon as the granulating area is smooth and

level (Fig 387) it should be dusted over with sulphanilamide and skin grafts should be placed on the top The grafts are covered with tulle gras and

Fig 385
Scarring from cordite burns

Fig 386
Keloid following scalding

some wool and a bandage applied (Fig 388) The actual technique of skin grafting and the plastic repair of contractures and scarring due to burns is considered in Chapter XIX It is essential that there should be close co-operation between surgeon and plastic surgeon in the treatment of war burns

Burns of the face—A large proportion of war burns occur on the face.

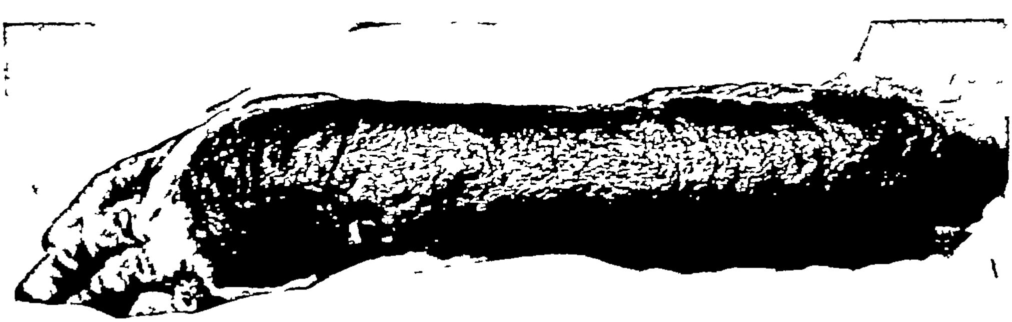


Fig 387
Extensive third-degree burn of forearm treated with triple dye for ten days Photograph taken just prior to skin grafting Note the healthy granulating area

and in some the eyelids are involved in the burnt area It is essential to prevent sepsis in facial burns because of the danger of erysipelas and the

formation of unsightly scars For this reason neither tannic acid nor silver nitrate should be used either in the primary cleansing process or subsequently (Fig 389) There is no danger whatsoever in using a gentian violet jelly or a triple dye jelly as a first aid measure as either of these jellies

Fig 388
Extensive burn of leg after skin grafting

are most suitable On admission to hospital continuous saline dressings can be applied and if there is any suspicion of sepsis sulphanilamide powder should be applied daily under a dressing of tulle gras In burns involving total skin loss on the face early skin grafting is essential if scarring is to be

Fig 389
Burn of face due to back flash from a gun. Treated with saline followed by triple dye. No tannic acid was used in this case. The pictures were taken with a five-day interval.

prevented It must be remembered that the skin of the face is very vascular and that in severe facial burns which cannot obtain hospital treatment for some hours or days it is essential to apply some coagulant antiseptic jelly to prevent serum loss from the burnt area Saline dressings cannot be applied to burnt sailors in small ships in the mid Atlantic by their fellow seamen if attempts were made in this direction by the time the ship reached

port the facial burn would be very septic. Likewise in a tank or aircraft which will not reach its base for five or more hours saline dressings are valueless

Coagulation therapy for facial burns has been condemned by some, but it is of real value in the Services and has proved its worth in the present war (Figs 390 to 392)

In those cases where the eyelids have been burnt some cod-liver oil should be applied to the area twice a day Wallace and Robson have found a paste consisting of 30 per cent. albucid (a soluble sulphonamide) and 10 per cent cod-liver oil in glycerine with equal parts of kaolin of value in facial burns. The paste is applied on gauze and is changed every third day

FIG 390

Bomb flash burn of face one hour after injury The skin of the face is split by blast in many places

FIG 391

Same case Seven days after injury

FIG 392

Same case Fourteen days after injury

Oliveros has had good results in Spain with an ointment containing 25 gm of cod-liver oil, 100 international units of vitamin A and 73 gm of lanolin The facial burn is washed with saline and the ointment is liberally applied and left for eight days The great disadvantage of such a method is the very disagreeable smell which pervades the whole ward, and these cases cannot be nursed on a balcony

In those cases which can be treated *ab initio* in hospital, saline masks can be used. After preliminary cleansing under anæsthesia, a gamgee face mask is made to fit the patient, openings being made for the mouth and nose The actual burnt area is dusted with sulphonamide powder and covered with tulle gras The face mask is then applied and kept continuously moist with saline

Burns of the hands—These form a problem of their own because they are apt to be treated in a manner which will not result in perfect recovery of function, an essential condition if men are to be retained in the fighting forces As a rule, burns of the hand alone are

likely to be less shocking than burns received elsewhere in the body Very often the hands are toughened and are less likely to pain and for this reason the burns are likely to be treated in a trivial manner

Tannic acid should not be used in the treatment of burns of the hands because the coagulum is very apt to contract and to press on the vascular supply to the fingers leading to necrosis of the terminal phalanges (Figs 393 to 395)

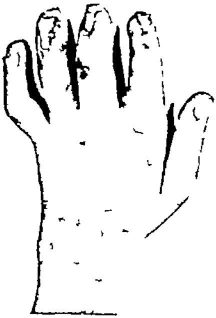


Fig 393

Contracted hand and terminal necrosis of phalanges which appear as sequestra. Treated with tannic acid.

Probably the skin of the hands harbours more organisms than other parts of the body and it is therefore most important that some antiseptic should be used as a first aid dressing Gentian violet jelly or triple dye jelly are suitable because of their antiseptic properties and the thin supple tan that they produce has no tendency whatsoever to contract If the case can be treated in hospital shortly after the injury the area should be thoroughly cleansed and washed with saline and then a solution of triple dye should be applied (Fig 396)

Fig 394

Radiograph of hand showing necrosis of terminal phalanges.

Good results are also obtained by treating the hand in plaster of Paris After cleansing under anæsthesia the whole of the injured area is covered with sulphonamide powder on the top of which a layer of tulle gras is applied. The hand is placed in the position of rest and a light plaster put on so that the wrist is immobilized but the fingers are free inside the plaster The plaster is removed after two or three weeks The patient is encouraged to move his fingers as much as possible while the hand is in plaster

Fig 395

Extensive third-degree burn of hand with terminal necrosis after being treated with tannic acid.

In some cases where the burn is extensive and involves considerable total skin loss, saline baths can be given twice or three times a day When the hand is removed from the bath it is carefully dried and powdered with

sulphanilamide and tulle-gras dressings applied The value of the saline

A
Condition before treatment, showing extensive blister formation from which hæmolytic streptococci were obtained

B
Condition after blisters were nipped and the hand treated with triple dye

C
Condition of hand three weeks after healing was complete, with full functional use

FIG 396
Large second-degree burn of hand treated with saline and triple dye

baths in some cases is very marked, the baths are soothing and the patient can be encouraged to move the fingers

In all cases where there is considerable total skin loss, skin grafting should be undertaken as soon as possible If the back of the hand has been burnt and requires skin grafting, a whole thickness graft should be used and can usually be obtained from the abdominal wall (Fig 397) During the present war there have been numerous examples where sailors have been severely burnt by burning oil, steam or petrol, due to torpedo attack or bombing, and these men have been forced to spend anything up to several hours in the sea because their ship went down In these cases the patients were not nearly so shocked as the medical officers would have expected, and the men themselves often speak about the absolute lack of pain while in the sea and its reappearance when taken aboard another vessel

FIG 397
Contracted hands Whole thickness graft on the back of right hand

These are practical demonstrations of the value of saline baths

Complicated burns—One of the real problems of war burns is due to the fact that a large proportion of these cases are complicated by other injuries fractures bomb wounds etc Under such conditions it is essential that the wounds and burns should be treated with a solution of triple dye and then encased in plaster of Paris

The closed plaster method of treating these complicated burns has proved valuable for it has allowed the early transfer of these cases from blitzed areas to some of the quieter country hospitals The plaster method has the merit of absolute rest to the part it allows of easy transport and the patients are free from pain

After treatment of the skin—Far too little attention is paid to the after treatment of the skin in burn cases When healing has taken place the patient and medical officer are apt to be too keen on discharge from hospital New skin following a burn is often thin and stretched over the underlying tissues This skin requires nourishment otherwise it will crack and become fissured when keloid formations may occur When healing has taken place it is important that the skin should be treated by the application of lanolin each day The amount of lanolin required is small and it should be gently massaged into the attenuated skin for several minutes The patient should be shown how to do this himself so that when he eventually goes on leave he can continue this treatment at home Lanolin should be used each day up to three months if good supple skin is to be produced in burn areas over the hands and fingers This is a very simple form of treatment but it is the simple things in life that are so difficult to inculcate into others By adequate after treatment and repeated monthly inspections the final results of war burns can be greatly improved and invaliding of useful personnel prevented in the fighting Services

Lanolin should also be massaged into the grafted areas when they have become incorporated into the surrounding skin

A word of warning must be given to all patients who have undergone grafting for burns and especially those in which a whole thickness graft has been used The full strength of the sun should not be allowed to fall on the grafted area for any length of time otherwise a chronic indolent ulcer may occur this is in fact a burn occurring in the graft The patient is quite unaware of the development of the burn because the graft is quite insensitive Several such cases have been seen during the present war There is a common tendency amongst the laity to consider that the rays of the sun will always prove beneficial to the patient no matter what disease or condition is under treatment It is essential therefore to warn every patient who has had a skin-grafting operation not to expose the graft to the full blaze of the sun

THE PREVENTION OF SCARRING AFTER BURNS

Scarring is one of the real problems in war burns because it frequently means that the sailor soldier or airman may have to be invalided from the Services for this reason alone Among civilians burn scars may cause the disruption of happy family life the husband or the wife using this as an excuse for a separation

Scarring cannot be prevented in deep burns if healing is allowed to take

place by the gradual ingrowth of epithelium over granulation tissue (Fig 398) However, when once the wound is completely covered with granulation tissue skin grafting should be employed

Fig 398
Contractures due to extensive third-degree burn

Superficial X-ray therapy has proved very valuable in the treatment of early keloids following burns This form of therapy should also be used after skin grafting if small fibrous tissue formation occurs between the grafts Two or three X-ray treatments cause these fibrous bands to melt away. In the navy a special superficial X-ray therapy unit has been installed in a hospital where most of the severe burn cases are treated

CHEMICAL BURNS

These are not uncommon in modern warfare, in fact they are much more common in the present war than in the last Such burns result from strong acids and alkalis, and may be seen as the result of bombing of chemical works or Service establishments where many accumulators are in use Here, again, it is the face and hands that are generally burnt, as the clothing protects the rest of the body The burnt surfaces should be thoroughly washed in running water for fully five minutes If an acid burn occurs the area should be treated with a solution of sodium bicarbonate, half an ounce to a pint of water If an alkali burn presents itself, a weak solution (1 100) of citric acid should be applied on lint and kept moist by the frequent addition of some more solution Six hours later the lint should be removed and the face treated with cod-liver oil, while the hands should be tanned with a solution of triple dye

Phosphorus burns—These may occur during a bombing raid as some bombs may contain phosphorus as an incendiary filling Should any particles of such a bomb become embedded in the skin of anyone who happened to be close to the scene of the explosion, the particles will continue to burn the skin unless rapid action is taken The burnt area should be covered with a gauze pad soaked in a 2 per cent solution of copper sulphate The action is to coat the minute particles of phosphorus with an inert compound by chemical action If no copper sulphate solution is at hand a water compress should be a d Oily dressings will only aggravate the burn, as phosphorus is readily oils and fats, and therefore on no account should they be u copper sulphate compress is removed the whole area shoul with triple dye (Figs 399 and 400)

were very common in the 1914-18 war and they have not

been infrequent in this war They may occur in gun turrets and in tanks and occasionally in munition works. The explosion takes place in a confined space and the burns are for the most part extensive and superficial and affect the face and hands (Fig 401) The burnt area should be washed with saline and then treated with triple dye

Fig. 399
Phosphorus burn of face

Fig. 400
Phosphorus burn of hand.

Petrol burns—These are common in all three of the fighting Services and also among the civilian population The burns are extensive and deep owing to the fact that the petrol soaks into the clothing and once alight is difficult to extinguish Many of these burns are fatal Shock is severe and the best form of treatment for extensive burns due to petrol is a constant saline bath Most of these burns cause total skin loss and therefore early skin grafting is necessary to prevent scarring and contractures

Phosgene burns—These are rarely seen owing to the fact that fatal syncope occurs before any treatment can be given This gas produces a first-degree burn which should be

Fig 401
Extensive third-degree burn of face, due to cordite. (Jutland coast action, 1916.)

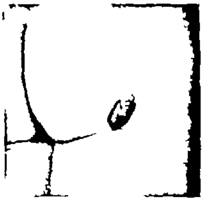


Fig 402
Mustard-gas burn on a lorry driver caused by sitting on a drop of liquid mustard gas. Burn occurred through three layers of clothing

Fig 403

Mustard blister, human forearm, biopsy about twenty-four hours Poly-morphonuclear infiltration of blister fluid well shown
(By courtesy of Professor G R Cameron)

Fig 404

Lewisite blister, human forearm, about twenty-two hours old Edge of blister showing complete and clean separation of epidermis Many necrotic poly morphonuclear leukocytes
(By courtesy of Professor G R Cameron)

treated with a solution of sodium bicarbonate prior to the application of gentian violet or triple dye

Mustard burns—These are as a rule severe and cause irritation to the eyes and to the respiratory passages Mustard gas is almost colourless and is generally used in the liquid form so that it soaks into the clothes and into the ground from which it evaporates If the liquid is left on clothes or boots it will penetrate in the course of a few hours and cause a burn (Fig 402) A big blister is formed by the separation of the epidermis from the underlying true skin (Fig 403) The actual burn should be treated with amyl salicylate and a compress containing this should be applied each day to the burn until healing takes place If amyl salicylate is not at hand triple dye jelly will be found satisfactory

Lewisite burns *are rapidly fatal unless prompt action is taken as absorp* tion from the burnt area is continuous Liquid lewisite causes an erythema of the skin followed by vesication (Fig 404) The best form of treatment is complete excision followed by a whole thickness graft If excision is not possible hydrogen peroxide should be liberally applied to the burn and repeated applications must be made

ELECTRICAL BURNS

Electric burns differ from all other burns in that they result from heat generated within the tissues while heat applied from without is responsible for the usual burn. Frequently contact with live wires or other electrically charged metals is established at more than one point or at one point and then is conducted through the body to the earth

The resistance offered by the tissues varies considerably Bone offers the maximum and skin the next greatest resistance and heavy calloused skin far more than delicate loosely textured skin Tendons and ligaments come next Blood is the best conductor in the body This is so because it is a fluid ladened with cellular elements and salts

In civil life electri cburns are seen most frequently in men working about high tension wires (1 000 to 4 000 volts or more) and since they are using pliers or other hand instruments the hands are frequently the location of initial contact In war electrified barbed wire is yet another example of the horror of applied science

PATHOGENESIS

The current is distributed throughout the body its path being regulated partly by the size of the exit contact or contacts The smaller the area of contact the greater the local damage Local areas of dehydration desicca tion or charring are usually observed As the current passes through the tissues the cells are destroyed as resistance mounts or due to the develop ment of steam within the tissues there is an actual cooking which leads to a rupture of blood and lymph vessels muscles and even bone Incompletely destroyed tissue may go on to gangrene or may become quite œdematous yet survive and eventually undergo extensive fibrosis leading to disabling

contractures and deformities Also peripheral nerve, brain and cord damage or destruction may occur, producing pain or paralysis or both

If charring has occurred there is usually little or no absorption, and the patient is comfortable and not toxic However, if charring is only a part of the pathological process, and immediate destruction has involved much other tissue, a profound toxæmia will be observed quickly There will be a concentration of blood, as shown by the hæmatocrit reading, or blood count and hæmoglobin estimate Often progressive changes have been started by the momentary contact, and for days following the accident they become increasingly evident as secondary necrosis occurs, so that what appeared at first to be a superficial or extremely limited destruction of tissue has now become widespread On other occasions the victim is bound firmly to the charged metal by a hand and foot, and the maximum and only resistance seems to be at the two points of contact Resistance is extreme and is continued for an indefinite time, until a companion can break the current The only damage, which may be extensive is limited to the two limbs, but complete charring is the rule

TREATMENT

All electrically burnt patients should be regarded as potential shock cases until observation proves otherwise Only under the rarest circumstances, if ever, should primary excision of the burnt area be performed Every effort should be made to preserve the line of demarcation to prevent a break at this point and to keep it sterile Neurological examinations are indicated, and they should be repeated frequently Excision of local areas of carbonized tissue should be postponed until granulation tissue has sealed or walled off tendon and joint spaces Visceral damage, electric in origin or secondary to toxic substances, must be anticipated, and its appearance will provide a bizarre group of symptoms Totally charred limbs may be amputated whenever the patient's general physical condition permits, or when specifically indicated by spreading infection Fasciotomy may be required to decompress œdematous areas, and ganglionectomy may be employed in late attempts to control pain and to improve circulation

In brief, conservative treatment will do most for the patient at first, but later highly specialized and definitive methods may be required to restore function

THE BUNYAN-STANNARD BAG

ENVELOPE TREATMENT OF BURNS

The envelope method of treating burns is the result of an attempt to evolve a practical system of treatment which would satisfy the following requirements for healing in a simple manner under active-service conditions These requirements were considered to be as follows —

Immediate—

(*a*) The removal of foreign bodies, stale blood clot and inflammatory exudate without trauma

(*b*) The reduction of inflammation and the removal of any irritant
(*c*) The transudation of altered tissue fluids and the attraction of fresh blood to the injured part
(*d*) Where necessary or desirable the surgical removal of dead or useless tissue
(*e*) The prevention of fluid and salt loss
(*f*) The relief of pain

During healing—

(*a*) The retention of a good blood supply
(*b*) The removal of inflammatory exudate and products of suppuration and necrosis as they form
(*c*) The control of bacterial growth in the wound and the prevention of putrefaction
(*d*) The prevention of secondary infection
(*e*) The restoration and retention of function as early as possible
(*f*) The protection of the wound from irritation of any kind
(*g*) The prevention of pain

From previous clinical experience some of the more important properties of electrolytic sodium hypochlorite and its superiority over the chemically produced hypochlorites were recognized and confirmation of this was found in the work of Carel and Dehelly and others It was therefore decided to employ suitable concentrations of a stock-solution of 1 per cent electrolytic sodium hypochlorite containing 16 5 per cent by weight of sodium chloride The dressing consisted of a bag made of specially impregnated silk provided with inlets at convenient points and sealed to the limb

Local treatment is carried out as follows —

Stage 1—Surgical removal of burnt tissue as in other methods but accompanied by douching of the burnt area with a solution of electrolytic sodium hypochlorite

Stage 2—The application of a suitable envelope or bag

Stage 3—Irrigation with an appropriate electrolytic solution thrice daily for twenty minutes until healing is advanced.

TECHNIQUE

Stage 1—Because electrolytic sodium hypochlorite solution on fresh burns does no more than sting in minor burns the administration of morphia is sufficient for the procedure As a rule gas and oxygen anaesthesia is necessary for the surgical toilet as in other methods of treating burns Waterproof sheeting is so placed below the burnt part as to allow the flow of electrolytic sodium hypochlorite solution to be collected into a large receptacle The solution is kept flowing over the lesion and surrounding parts until the envelope is applied.

Stage 2—A suitable envelope is put on (Fig 405) The envelopes are made in stock sizes to fit limbs and other parts

TABLE OF CONCENTRATIONS

Parts of stock solution in tap water 1 per cent electrolytic sodium hypochlorite containing 16 5 per cent by weight of sodium chloride, obtained from electrolytic cell or commercially as "Milton"

Degree of Burn	Concentration	Temperature	Duration and Frequency	Notes
First-degree Burns—"Household"	1 2 or full strength	As from bottle	Once for ten to fifteen minutes	Pain and inflammation quickly relieved
Second degree Burns—Skin unbroken	1 4 to 1 5	100° to 110°	For twenty minutes	Blisters may be aspirated, then filled with 1 20 E S H and the skin pressed flat
Skin broken	1 10 to 1 5	100°	For twenty minutes and during any cleaning or surgical work	Morphia as indicated or light gas and oxygen
Third-degree Burns—Primary	1 4 to 1 2	100° to 115°	For a few minutes during resuscitation and during the whole period of surgical preparation	Morphia or light gas and oxygen where indicated
Secondary	1 4 to 1 2	100° to 115°	During the whole period of surgical cleansing	Light gas and oxygen

FIG 405

The envelope method of treating burns Note the entrance and exit diverticula for irrigations

Various instruction sheets[1] have been issued of which the following is an example (p 527)

[1] Irrigation Envelopes Ltd , 12 Brewery Road, London, N 7 Telephone North 1050

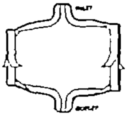
(KNEE)

1 Checking Dimensions

This Envelope is for application to the Knee. Envelopes are made in suitable sizes for the following limb measurements:

	Small Adult	Large Adult
Length	12 in	12 in
Circumference (top)	13 in to 16 in	16 in to 20 in
Circumference (bottom)	10 in to 13 in	13 in to 16 in

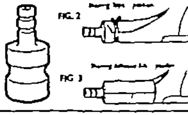
Before applying an Irrigation Envelope make certain that you have obtained the correct measurements of the limb. If you have, the appropriate envelope will fit.



2 Fitting Outlet Nozzle

The outlet nozzle is inserted into the envelope outlet, leaving the grooved leg tube clear of the outlet. Tie the nozzle in the outlet with ordinary cotton tape (Fig 2), and in order to make the joint watertight, bind with waterproof adhesive plaster (Fig 3). Insert the protruding end of the nozzle into rubber tube, which should lead into receptacle to receive the used fluid. Adequate and efficient drainage can be obtained without the outlet nozzle when the limb can be freely moved and put in dependent position over the waste container. If the limb immobilised or for any other reason, length of rubber tubing is required to carry the used fluid to the container an outlet nozzle should be fitted.

FIG 1 FIG. 2 FIG 3



3 Fitting the Envelope

IMPORTANT

In all cases the seal should be made at least two inches from the margin of the wound.

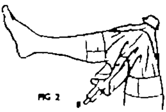


FIG 2

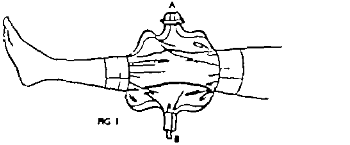


FIG 1

Slide the envelope into the required position on the limb, taking care that the inlet (A) always on top. The outlet (B) will then be in the correct position.

The envelope is sealed above and below the knee. When fitting full allowance should be made for the knee when bent (Fig 2) to prevent any strain on the envelope and to allow complete freedom of movement.

It can also be used to envelop areas above or below the knee, but under no circumstances should the seal be fixed within 2 in. of the knee joint to avoid restriction of movement.

4 Sealing the Envelope

When the band of the envelope encircling the part of the body on which the envelope to be sealed, strip the protecting gauze from the adhesive inside the envelope (Fig 1) and take two, or three, pleats in the adhesive, Fig 2. Strip the protecting gauze from the adhesive outside the envelope and press the pleats flat on to the limb. The adhesive on the envelope provided to enable the circumference of the envelope to be reduced to that of the limb by taking the surplus material into two or more pleats. The adhesive ensures that the fold will, by sticking together, make watertight pleats. So far as possible, the fullness in the envelope (created by making the pleats) should be distributed over the injury. If the injury on top of the limb, make pleat on either side and fold towards the top of the envelope. If the injury extending all round the limb, make three pleats and fold so that the fullness distributed all round the limb.

Pass piece of webbing plaster twice round the limb, so that half its width is on the adhesive portion of the envelope and half on the skin, Fig 3.

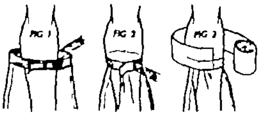


FIG 1 FIG 2 FIG 3

5 Closing Inlets & Outlets

The inlet closure clip (Figs 1 and 2) is used to close (a) inlets not being used during the irrigation process (b) all inlets between period of irrigation (c) outlet where outlet nozzle not fitted.

To apply remove gauze and fix in position (Fig 1), folding over to close (Fig 2). Because the special adhesive on the clip can be used many times can be unsealed (Fig 1) for each irrigation and closed again (Fig 2).

An alternative method of sealing irrigation inlets and outlets (in the absence of nozzles) to use the rubber sealing clip (Figs 3 and 4).

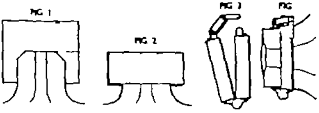


FIG 1 FIG 2 FIG 3 FIG

6 Maintenance & Repair

The adhesive portion outside the envelope will stick to the limb for few days but is not designed to adhere so securely that will form watertight seal this achieved by the special webbing plaster.

If the seal shows signs of leaking the original webbing plaster can be removed and replaced with new strip but the part of the envelope affected and the surface of the skin should first be cleaned with ether meth to dry the surfaces and permit sealing.

Should it be necessary to repair an envelope of which not too large portion has been torn or punctured this can be done in the following manner:

(a) dry thoroughly (b) clean the area round the leaky or torn part with ether meth (c) to ensure perfect seal, apply piece of waterproof adhesive plaster considerably larger than the leak area.

Fig 406

Stage 3—Irrigations are commenced

IRRIGATIONS

Degree of Burn	Concentration	Temperature	Duration and Frequency	Notes
Second-degree burns	1 20	100	Twenty minutes three times a day	In a few cases irritation occurs and concentration should be reduced to 1 40 E S H, providing irritation is not due to inefficient cleansing
Third-degree burns	1 20	100	Twenty minutes three times a day	

Concentration should be increased on every third washing if inflammatory exudate is excessive or the products of lysis of the necrotic tissue are not effectively removed Remove envelope after six to seven days, wash in electrolytic sodium hypochlorite solution and treat burn as in initial treatment

RESULTS OF TREATMENT OF BURNS BY THE ENVELOPE METHOD

The method has been used for over a year It has been found that providing the treatment is carried out as recommended, consistently good results are obtained even in a Cottage Hospital

Some of the advantages of the method are as follows —

Fluid loss is stopped almost immediately, and in most cases pain is relieved quickly

Movement of a burned limb can be encouraged from the start, this is especially valuable in cases of burns of the hand

The supervention of toxæmia is unusual, for products of tissue breakdown are neutralized and washed away as they form

The patients are very comfortable and their morale is high, particularly as they are sociably acceptable to their fellow-patients

The danger of cross-infection is reduced to the absolute minimum Under this treatment new epithelium grows rapidly and is of excellent quality, in particular the new epithelium over joints is so supple that restriction of movement does not occur

The technique of irrigation is simple and does not entail a strain on the nursing service Nevertheless, it is essential that the nursing staff should understand the rationale and receive full instruction on the conduct of routine irrigations

Further observations are in progress on the use of the method in cases of combined burns and wounds, on severe compound fractures, septic wounds, crushes, septic fingers and infected tendon sheaths and various types of ulcerations The results are promising, particularly from the point of the comfort of the patient and the early restoration of function

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CHAPTER LI

FROST-BITE AND TRENCH FOOT

FROST-BITE

WHEN the body, as a whole or in part, is exposed to cold the pathological effects which ensue are best understood if they are divided into two sections, general and local, with the recognition that general effects may follow total or partial exposure and local effects may have general ones superimposed

The maintenance of an appropriate body temperature is a prime necessity of all forms of warm-blooded life, and so efficient are the means adopted to this end that very prolonged exposure to severe cold is necessary before the balance between heat production and conservation, and heat loss becomes disturbed so that the body temperature falls

General effects of exposure to cold can be subdivided into two categories (1) those which occur when the exposure is not severe enough to lower the general temperature, (2) those which follow when the body temperature continuously falls

In the former group are placed some of those illnesses which occur chiefly in the winter months and which mainly affect the respiratory tract Many of these are primarily infective conditions, and what part cold plays in their incidence is not sufficiently determined

In the common winter cold, for instance, it is possible that the inspiration of cold air renders the nasal and other respiratory mucosæ less able to withstand the attack of the invading organisms or viruses, in other examples of "winter complaints" there may be some general lowering of vitality and of resistance to infection, but undoubtedly other factors than cold, *i e*, lack of sun shine and fresh air, here play their part

When the exposure is so severe that it produces a heat debt and the body temperature falls, a set of much more urgent and serious symptoms arises According to those who have had an opportunity of observing such cases, there is at the onset a loss of energy and a feeling of great fatigue, this is often associated with a loss of the normal urge to struggle for life, so that the victim resigns himself to his fate When the body temperature falls to about 68° F there is an overpowering desire to sleep, and coma shortly supervenes Those few who have survived these experiences state that the sensations are not unpleasant Apparently life may be maintained for some time in this state, for recovery has been shown to be possible after several hours' unconsciousness This agrees with observations on animals found "frozen" which revive when the temperature is raised

Experiments on animals subjected to severe general cold show that respiration, after an initial quickening, slows and finally ceases, while at a slightly later period the heart-beats (ventricular) also slow and stop Such animals are not beyond resuscitation, even after several hours, and may be apparently unaffected by their experience Below a certain temperature the thermal controlling

centres fail and the internal temperature follows that of the surroundings, like a cold blooded animal (poikilothermic) In some normally hibernating species there are indications of the same process at work

Exposures as extensive prolonged and severe as those employed in animal experiments can arise but rarely in human experience but neverthe less authentic reports from the recent Finnish and Russian campaigns reveal that large numbers of men have been found completely frozen and similar records are received of shipwreck survivors exposed to icy cold wind and sea In all these cases it is to be suspected that there were powerful predisposing factors at work since it is well recognized that lack of food debility hæmor rhage and toxæmia from wounds undermine the ability of the body to maintain its normal temperature

The various mechanisms by which the body attempts to maintain a general temperature compatible with full vitality are all protective of the individual although not of necessity equally so of the exposed part or region Indeed as the local changes associated with exposure to cold are studied it becomes increasingly obvious that the body is often compelled to sacrifice the local tissues in the efforts it makes to preserve general vitality This is possibly a novel conception of the process but the underlying principle of local sacrifice to conserve the whole is one which can be applied to other pathological processes and is of course in complete accord with biological philosophy both in the colonies of cells which constitute the individual and in the larger colonies of individuals which form the families tribes herds and other aggregations of life throughout the animal and vegetable world

These mechanisms vary in importance there is even some evidence that in minor exposures to cold the reactions are directed only to local protection the incident being too insignificant to call the general means of protection into play Possibly this is the real meaning of the periodic local dilatation which Lewis has described and which he attributed to an axon reflex since it remained after the nerve had been divided but not if sufficient time had elapsed for the nerve to degenerate peripherally

Against more severe[1] exposures protection is achieved in the following ways —

1 The skin is normally covered with a thin layer of greasy sebaceous material which acts as a bad conductor but more importantly tends to induce supercooling the benefits of which will be described later

2 The subcutaneous fat imposes another thermal barrier between the surface and the deep structures

3 The superficial vessels contract so that less blood is delivered to the cold skin surface With severe exposures the deep vessels will subsequently be affected but owing to difficulties of observation it cannot be stated that they respond in the same manner as is well known there is usually a reciprocal relationship between the deep and superficial blood supplies

4 Sweating is reduced or abolished with a corresponding saving of the heat loss both in secretion and evaporation Related to this is the cooling effect of the inspired air which is said to amount to 15 to 25 per cent of the total heat loss As already noted in animal experiments respiration is

[1] The term "severe is here used to include the temperature fall as well as the length of exposure (which, as would be expected, is an important factor) Thus severe exposure may mean exposure to intense degrees of cold or more prolonged exposure to lesser degrees.

slowed, but in human experience this is unlikely to occur until a late stage on account of other factors (such as the rarefied air in mountaineering)

5 In the earlier stages, shivering occurs in an attempt to increase heat production

6 Contraction of the pilomotor muscles is obviously a very minor aid to heat conservation in man, although in animals it has this effect by making the hairy covering thicker

7 There is increased heat production in the body generally by several means which need not be elaborated here, they include stimulation of the adrenals and the thyroid, liberation of glycogen from the liver, etc

8 It will be noted that many of these effects depend upon the sympathetic nervous system for their development This accords with Cannon's observations upon his sympathetically denervated dogs which were unable to withstand cold and became practically poikilothermic

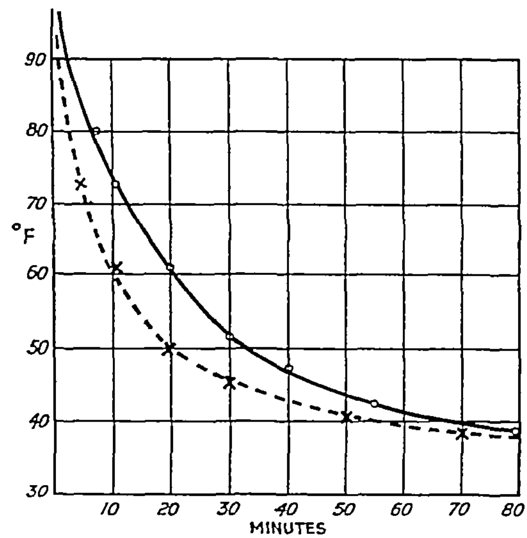

FIG 407

Rates of cooling, when exposed to cold, of kitten corpse and of living anæsthetized kitten, compared Continuous line is corpse, broken line is living animal The initial rate of fall is much greater in the living animal owing to superficial circulation of the blood. As the circulation slows and fails, however, the rates are equalized

The effect of the circulation in distributing temperature changes is well seen (Fig 407) by comparing the cooling curve of the corpse with that of the anæsthetized living animal The importance to the body of restriction of the superficial circulation by vasoconstriction is thus emphasized

When an animal *dies* as a result of severe exposure to cold its condition is really one of suspension of animation, so that it is not surprising that resuscitation should be possible when the temperature is raised The plentiful stories of animal resuscitation are thus confirmed in the laboratory, there are, however, certain secondary problems which have to be overcome, such as the initial raising of the blood pressure, which becomes increasingly difficult as the age of the animal increases The body of an animal which has died of cold (provided a certain critical temperature has not been passed) is comparable with an internal combustion engine in perfect condition and having plenty of available fuel which will never start spontaneously but requires an initial turn of the crankshaft to produce the first explosion In the case of animals there is no residual blood pressure during the state of suspension of animation, and so when thawing out it is necessary to raise it artificially in order that the heart may receive its initial impulses On occasions in very young animals the heart has been seen to start spontaneously and recovery has followed without artificial aid It is unlikely, however at present that attempts at resuscitation of frozen human beings would meet with success, for not only are the technical difficulties great but in most instances the frozen state has been preceded by such serious pre-

disposing conditions as wounds loss of blood starvation general debility etc The general effects of cold while of great experimental interest are therefore of little practical importance

Local effects of cold—The local effects of cold especially in times of war have been recognized and studied for many years Napoleon s surgeon Baron Larrey described the ravages of cold during the ill fated attack on Moscow He was the first to recognize the condition which is now known as trench foot and *showed that it was not extreme cold which was responsible* but lesser degrees associated with wet Again in the Medical History of the Crimean War (1854) it is pointed out that it was in cold wet weather that these troubles became prevalent A clear distinction is here made between true frost bite and the gangrene due to *cold and debility* when the temperature was always above zero From this time to the commencement of the last war articles in similar vein appeared as a result of experiences in the Tibet Mission Force and the Balkan wars On the whole however the armies engaged in 1914 were unprepared for the great number of cases which the special circumstances of static trench warfare produced The magnitude of the problem is indicated by the fact that no fewer than 85 000 cases are reported in the Official History of the War to have occurred in the British Army alone This number would be enormously increased if the figures of the French Russian and German armies were added These *alarming figures naturally commanded investigation as a result a large* number of articles were written and a good deal of experimental work was carried out which increased both our knowledge of the pathology of the condition and our ability to suggest methods of prevention and treatment Since no description of the clinical aspects of trench foot and frost bite can mean much unless the underlying pathology is understood it is necessary to give a brief survey of this work which forms the basis of our present knowledge and which has been extended in the inter war period with general confirmation of the earlier findings and with certain important additions

In 1915 Smith Ritchie and Dawson published an account of their *experimental production of a condition closely resembling trench foot* by exposing rabbits to wet and cold under varying circumstances It must first be noted that they found it difficult to produce any pathological change this should remind us that great caution and reserve must be exercised in comparing clinical experiences and experimental work on animals which not only have a pronograde posture but also exceptionally well-developed defence mechanisms The conclusion of these observers was that the main effect of cold was on the blood vessels which after exposure allowed tremendous transudation upon this the subsequent changes depended They also formed the opinion that the effects of mild wet cold over a long time were different only in degree from those of short exposures to severe dry *cold* A *further* important point was their demonstration of the bad effects of slight constriction by rubber bands an observation entirely in agreement with clinical observation in the trenches

At this time while engaged in certain experiments upon the growth of tissues *in vitro* (with an entirely different end in view) I found that individual tissues and growths *in vitro* appeared to be unaffected even by prolonged exposure to cold providing actual freezing was avoided Thus portions of

explanted heart, growing and pulsating vigorously *in vitro*, could be stored at a temperature of 0° C for several days (sometimes for weeks) in complete inactivity, to resume active growth and pulsation when the temperature was again raised to that appropriate for the animal concerned Similarly, growth occurred more readily in explants obtained from tissues which had been stored for several days in the ice chest than in those obtained freshly from the animal I am informed that the same observation applies to human corneal grafting—cold-stored grafts take even better than fresh ones

By various means the vitality of these cold-stored explants was tested and the results showed that there was no diminution, they could in no way be distinguished from those in which life had been maintained at full flow in the incubator In other words, there was true suspension of animation. The conclusion was justified that when cells were isolated from vascular nervous chemical, and physical influences which their connection with the body normally entails they remain unaffected by moderate degrees of cold. Since trench foot, therefore could not be due to any direct effect of cold upon the cells it must in some way be due to one or other of these possible influences, and as all of them would be very depressed or totally abolished about 0° C it seemed likely that the harm was done chiefly during the thawing-out period When the vascular and nervous responses were investigated in the intact animal it was found that division of the somatic or the perivascular sympathetic nerve supply failed to prevent the effects of exposure—indeed in the latter case the manifestations of trench foot were even more severe than in the controls The vascular experiments were more productive and it quickly became obvious that any means of restricting the blood supply during the thaw period was of value

Local vasoconstrictors of various sorts were successfully used and ultimately the paradoxical conclusion was reached that frost-bite gangrene of the skin of an animal's foot could be consistently prevented by tying the main artery to the limb In human experiments the effects of experimental frost-bite were often completely abolished by the use of local vasoconstrictors (adrenalin, etc.), while in the control areas the skin sloughed and left permanent scarring

In all the successful experiments the vascular transudation was absent. so that it was clearly this which, by cutting off the blood supply locally, led to gangrene That this idea of the pathology was probable received support from the observation that multiple incisions or punctures which allowed the exudation to escape also prevented gangrene At the time it was believed that the vascular phenomena were physical in nature, but in the light of Lewis' subsequent demonstration of the H substance it seems probable that the effect is really a chemical one

CRITICAL TEMPERATURE

It was well known that exposures to very severe dry cold could produce immediate (or very rapid) death of tissues and it therefore appeared that there might be a critical temperature beyond which tissue recovery was impossible To determine this tissues growing *in vitro* were again used It was found that exposures to temperatures in the region of − 5° to − 7° C

produced immediate death This was the point of solidification of the cellular protoplasm (the tissue fluids may freeze at a higher temperature) and intimate observation of intracellular structure after such exposures showed that the protoplasmic framework was disrupted It must be emphasized that the mere exposure of parts of the body to these severe degrees of cold does not warrant the assumption that the tissues themselves have reached the critical temperature so responsive are the protective mechanisms and so great is the insulating power of the tissues When care was taken to ensure that these temperatures had been surpassed in animals and in man death of the particular tissue invariably occurred *This critical* temperature of -5 to -7 C was far below that expected from the known

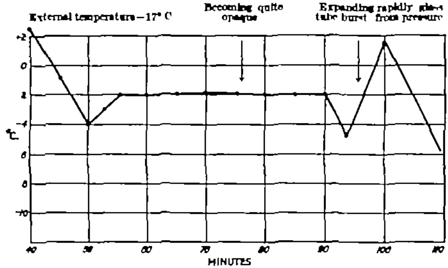

Fig 408

Lower portion of cooling curve of 10 per cent. gelatin in water At 50 min. supercooling is displayed, followed by a slow rise in the temperature to −2, at which it remains while certain physical changes occur At 75 min. the whole loses it translucency and after 90 min. there is explosive expansion which breaks the containing tube. The erratic behaviour of the curve here is probably due to direct pressure effects upon the bulb of the thermometer The slow rise after supercooling is explained by the fact that the more fluid phase of the gel is the disperse one This should be compared with Fig 409

crystalloid and colloid content of protoplasm but a further series of investigations on the cooling curves of different tissues showed that the discrepancy was due to the invariable exhibition of the phenomenon of supercooling when substances in the colloidal state are frozen Somewhat similar curves could be obtained from many natural colloids such as gelatin (Fig 408) the ultra microscopic structure of which was known so that comparing these with the tissue curves (Fig 409) it became possible to hazard a guess as to the ultimate structure of the protoplasmic colloids

The fact of supercooling must be recognized in the interpretation of the effects of cold on tissues it is undoubtedly the explanation of some of the apparently discordant results which different experimenters have obtained Lewis and Love subsequently reached the very important practical conclusion that supercooling may be abolished *in skin by soaking it* in water or facilitated by leaving the natural sebaceous secretions intact or by

rubbing in oils It is worthy of note that supercooling introduces a time factor into the question of clinical frost-bite which is not revealed in *in vitro* experiments owing to the small mass of tissue concerned

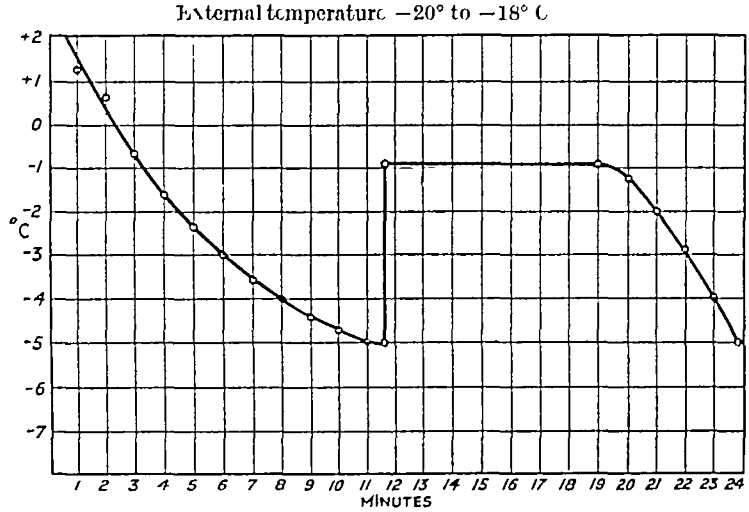

Fig 409

Lower portion of cooling curve of fresh rabbit muscle Supercooling is displayed between 3 and 11 min when the temperature reaches −5 Then there is a sudden rise to the theoretical freezing point and the protoplasmic structure is disrupted This quick rise suggests that in muscle protoplasm the more fluid phase of the colloid is the continuous one, i e, that it is an emulsoid The explanation of supercooling rests with a study of molecular physics

The effects of true frost-bite, therefore, are determined at the time of exposure (not subsequently during the thaw as in trench foot) and cannot be avoided by restricting the blood supply or other measures successful in trench foot But while this is true, it must be realized that surrounding the frost-bitten area is a zone in which the critical temperature has not been surpassed, and that this region, usually of much greater extent and mass than the frost-bitten area, will display all the phenomena of transudation, etc , upon thawing Clinically this violent reaction may completely mask the tissue destruction due to actual frost-bite

A study of the survival periods of living tissues at different temperatures (Fig 411) will help to complete and explain the pathological picture This curve was obtained from experiments upon isolated tissues growing *in vitro* one of its most interesting features is the depression between 25° and 10° C The probable explanation is that metabolism is a two-sided process consisting of a building up (anabolism) and a breaking down (katabolism) The former, being absorptive of energy, will naturally cease earlier with fall of temperature than the latter, which gives out energy As long as the temperature is above a certain limit life proceeds almost indefinitely, but as the temperature falls anabolism ceases before katabolism, so that the period of survival is limited At lower temperatures still, katabolism also ceases and the survival period increases until from just above zero down to the critical temperature life can be conserved for long periods again When an exposed area is cooling this dangerous temperature zone must be traversed,

and again in the reverse direction and usually for a shorter time during the thaw The zone between 25 and 10 C is thus passed through twice the katabolic products then liberated (metabolites) accumulate in the tissue spaces owing to the vascular occlusion and are responsible for the sub sequent transudation It will be seen that this conception fits in entirely with Lewis work on the H substance and it would suggest that if this zone could be traversed quickly there would be less metabolites to accumu late There is some experimental support for this idea but it is not yet proved

The histological changes in frost bite of the two degrees were observed by Rischpler in 1900 and by Smith Ritchie Dawson and others There was dilatation of the small vessels with swelling of the intima and some vacuolation of the muscle fibres of the media but no thrombosis The main effects were evidently upon the vessels all the other changes seen such as swelling and disintegration of fibrous tissues etc were to be explained by the tremendous exudation from the vessels Some workers recorded thrombosis but in these cases the critical temperature had possibly been passed

Experimental work such as that described is of necessity somewhat academic the handling and prevention of cases of frost bite can be logical however only if founded upon sound pathological principles These may be summarized as follows —

1 Down to the critical temperature cold has no effect upon the individual cells of any tissue but in consequence of the retention of metabolites a violent vascular response occurs during the thaw which leads to excessive transudation of fluid from the vessels This may be under pressure sufficiently great to obstruct the blood supply especially to the superficial tissues skin etc and lead to gangrene In lesser degrees the transudation which contains fibrinogen ends in fibrosis of the skin and subcutaneous tissues with permanent hardening and loss of elasticity and with constriction of blood vessels which renders the victim prone to all the manifestations of imperfect blood supply

2 The critical temperature appears to be in the region of −5 to −7 C it is not absolutely constant owing to the display of supercooling The external temperature necessary to bring about reduction of the tissue to the critical temperature will of course be much lower and will depend upon other climatic conditions such as wind etc Rarely will the exposure be severe enough to affect more than the superficial structures skin etc the deeper parts being protected by the heat of the body the poor conduction through the fatty layer and the slowness of supercooling Nor is mere solidification of a part sufficient evidence that the cells have also solidified for it is probable that the tissue fluids between the cells freeze at a higher temperature than the colloidal protoplasm

Below the critical temperature cellular life is destroyed and no recovery is possible In practice the effects of true frost bite are usually very limited in extent and are often completely masked by the reaction occurring in the surrounding parts which have not been below the critical temperature In passing it may be noted that in certain modified forms i e the inspissated state of the spores of bacteria protoplasm will withstand much lower

temperatures than those here mentioned, which apply only to the succulent living cells of warm-blooded animals.

3. Experimentally the effects of the changes described in (1) can be prevented by restricting the blood supply to the part and to a lesser degree by drawing off the transudation as it occurs. The effects of true frost-bite (2) are determined at the time of exposure and thus cannot be avoided.

During the 1914-18 war many theories were advanced to account for trench foot. Some observers believed it to be infective, due to bacteria or fungi, others to changes similar to acidosis, or to the effects of water. It is now generally agreed that cold is the primary factor and that any others are purely subsidiary.

DETERMINING CONDITIONS

The conditions under which the effects of exposure to cold are likely to be encountered are very varied. For special reasons military undertakings are particularly liable to suffer, especially in certain regions and at certain seasons. Mention has already been made of the devastating effects of cold upon Napoleon's armies in their march to and from Moscow; the records of the Crimean War give ample accounts of its incidence there, and there were an enormous number of cases during the last Great War. It should not be overlooked that similar conditions occur in sea warfare mainly among shipwrecked men, and in aerial warfare. Polar expeditions and mountaineering exploits add to the possible circumstances but the conditions are, of course, constantly met with in those parts of the world where the temperatures reach exceptionally low levels, such as Siberia and Canada.

The reasons why military operations are so important in this respect are (*a*) the large number of men involved, (*b*) the general circumstances of warfare in which efficient preventive measures become difficult and sometimes impossible to apply, and in particular the special conditions of static trench warfare, from which the term "trench foot" arose.

TRUE FROST-BITE

There are naturally many fewer victims of this form than of trench foot, and the parts affected are different. At the temperatures at which true frost-bite occurs all water has been converted to ice and so the surroundings are completely dry. Those parts of the body which are normally clothed, including the feet, are thus largely protected, but the hands, face, nose and ears are frequently involved. Raymond Greene, whose experiences on the Kamet and Everest expeditions were unique, thus describes the onset: "Sudden frost-bite develops in exceptionally cold weather, especially in a high wind or when exposed skin is brought into contact with cold metal. A sting like that of a wasp is usually felt, but sometimes it is painless. The skin is white and crystalline. If it is observed at once and a warm hand clapped on it, no harm may be done. During thawing a red area appears around the frozen patch which gradually invades it. The surroundings gradually return to normal, leaving the patch red and sharply defined.

Shortly afterwards itching and swelling begin The wheal may take many hours to subside or blistering may follow and even deep gangrene of the skin Gradual frost bite may occur on exposed skin or on well-clothed parts The burning sensation of extreme cold dies away and a pleasant numbness takes its place At this stage the skin may appear normal or may be white and waxy If freezing continues there is destruction of tissue blood vessels give way œdema and hæmorrhages develop and the vitality of the tissues is destroyed—a course of events which may occasionally be delayed by cold so extreme that the normal contour of the part is preserved as in marble A frost bitten hand may have precisely the appearance of a hand in which the main arteries have been blocked by embolism

It must again be emphasized that usually only the most superficial tissues have passed the critical temperature and so the permanent loss of substance by direct effect of cold is very limited in depth The deeper structures have however been subjected to sufficient depression of temperature to produce the great transudation associated with chilling (i e trench foot conditions) Unless con trolled this will cause further tissue loss on thawing In severe cases the transudation is hæmorrhagic the whole region becoming deep purple in colour with blood filled blisters and blebs During the recovery stage the dead tissue in the absence of infection becomes dry and black and slowly separates by the formation of a line of demarca tion If only the skin is affected this dry scab acts like the coagulum of a burn treated by tannic acid it is often surprising how much epithelializa tion can occur beneath it The parts which recover remain swollen for a considerable time and there is obvious evidence of fibrosis and loss of elasticity There is generally a long lasting disturbance of sensation in the form of anæsthesia paræsthesia and hyperæsthesia In the digits nail growth is interfered with the nail is usually lost and is replaced by a per manently deformed one From the point of view of prognosis it is well to bear in mind that the frost bitten part looks worse than it really is

FIG 410
Gangrene of the toes due to frost bite

PREVENTION OF FROST BITE

The prevention of true frost bite has been learned in the hard school of practical experience in the various polar and mountaineering expeditions of the past and also from a study of the methods universally practised by dwellers in Arctic regions Esquimaux etc The clothing should be in as many layers as possible and made of a heat retaining material wool despite certain artificial substitutes being still the best To retain the layers of air thus imprisoned it is essential to counteract the effects of wind for whereas an external temperature of - 4 5° C will induce frost bite in a

high wind, temperatures well below the critical point, *i e*, $-13°$ C, may be reached without effect when the air is still (Brahdy) This is achieved by an outer layer of impervious material sufficiently robust to withstand wear, but light and flexible, to avoid embarrassment to the wearer Leather is suitable (hence the fur-lined coat) but rather clumsy, other wind-proof materials, such as Grenfell cloth, proved very satisfactory on the Himalayan expeditions Clothing must not be tight—particularly does this apply to socks and boots Gloves and helmets should have the same characteristics, the former being slung round the neck so that the hands can be readily removed for essential purposes and as easily reinserted For long the belief has been held that oiling the skin was a good preventive measure It can scarcely be believed that such a thin film of oil can have much effect in insulating the tissues thermally, although some tests carried out in the last war, in which the legs and feet were exposed for an hour to cold water while the general body temperature was recorded, showed a fall of 1 4° F for bare legs but only 0 2° F when the legs and feet were well rubbed with oil (Yarrow) Lewis' observation that oiling the skin helped to induce supercooling, however, indicates that for severer exposures the method may be really protective In this case the oil probably acts in the same way as the oily film often used in the laboratory to cover a fluid in which it is desired to display supercooling It is stated that animal or fish oils or semi-solids, such as vaselin, are better than vegetable oils, as is well known, whale oil is one of the favourites This will be further considered under Trench Foot

General debility and malnutrition were correctly recognized as predisposing factors as early as the Crimean War Often debility is associated with a vitamin deficiency, especially of C, as in the Scott Antarctic Expedition These are points which must not be overlooked in considering prevention (see "Trench Foot," later)

TREATMENT

The treatment of true frost-bite commences with the thawing of the part, this must be carried out slowly and gently The means of thawing should be kept only slightly above the temperature of the frozen part and progressively raised in temperature just ahead of the reviving tissues In many cases all that is needed is protection from further cold, the heat of the body itself being allowed to thaw the part out slowly Greene stresses that there should be no rubbing, for "the skin of a frost-bitten limb is in a most delicate state, and the gentlest rubbing may well destroy its chance of survival" He also believes (anyhow in mountaineering experiences) that anoxæmia is an important contributing factor, and advocates the administration of oxygen during recovery Whether this factor is equally important at lower altitudes is not yet known

The mildest cases, after a reactionary period, may recover almost completely, perhaps with some superficial desquamation and transient disturbances of sensation In severer cases the surface layers are already destroyed to a varying depth and will ultimately separate and come away The problem of the reconstitution of the skin is now similar to that occurring in burns

Where islets of epithelium glands hair follicles etc remain alive extension of epithelium takes place under the dead layer forming a new but structurally modified skin. In still more severe instances the process involves the deep tissues, leaving a raw area which will ultimately require skin grafting or amputation depending upon its site The terminal phalanges are particularly likely to suffer severely and may finally undergo spontaneous amputation

The treatment of these lesions is not peculiar to frost-bite once the period of thaw has passed but is conducted upon the general principles applied to burns etc Secondary infections are not uncommon and tetanus is stated to fulminate in frost bite and trench foot so that antiserum must be used prophylactically When tissue loss has been considerable the subsequent measures to restore function or appearance are carried out according to well established orthopaedic and plastic principles but it is well to remember that the parts surrounding the lost tissue have themselves been subjected to severe cold and in consequence they form poor material for the fashioning of flaps and are liable to delayed healing easy infection and even further gangrene A good time should therefore elapse before such secondary operations are undertaken and every means must be taken to improve the condition of the tissues in the interval

TRENCH FOOT

As in true frost bite the essence of prevention is to avoid undue chilling of the tissues but here we have the additional factor of wet to contend with since the provocative temperature is round about but not below the freezing point Water is a good thermal conductor so that if it is in direct contact with the skin it will be almost impossible to prevent such local heat loss as will reduce the temperature dangerously It is necessary therefore not only to isolate the part thermally as in true frost-bite but also to render the whole waterproof As the name implies the state of trench foot is almost limited to the feet although the experimental studies have shown that a similar condition exists in the tissues surrounding a region of true frost bite The wearing of long waterproof boots extending well above the level of the water or slush and large enough to accommodate two or more pairs of socks or stockings is obviously required Leather if kept well oiled is waterproof but rubber boots require less care and are more economical so that gum boots are now universally used for this purpose The oiled silk stockings suggested by Délépine in the last war proved to be difficult to manufacture properly and to have very poor wearing properties All watertight materials also retain perspiration and if this be excessive will defeat their object but in the static conditions of trench warfare sweating is unlikely to be excessive except in those few who normally suffer from hyperidrosis The boots however should not be used for marching and like the socks should be quite dry when issued Obviously socks must be changed before they become wet and sodden being replaced by fresh dry ones For the shipwrecked it is suggested that dry socks might be stored in sealed canisters carried in the lifeboats Socks wet with sea water are notoriously difficult to dry by such expedients as placing them inside the clothing of the wearer When possible trenches are to be kept

dry by drainage, alternatively, the men can be provided with platforms, duck-boards, etc., to keep them above the water-line This is particularly important when cold periods are followed by intermittent thaws Since venous congestion and stagnation predispose, attempts must be made to avoid these, men should not rest with the feet dependant, and especially over the edge of a seat or fire-step, movements of the limbs are to be encouraged, and all tight clothing, such as puttees, prohibited The relationship of heavy smoking to peripheral vascular spasm has been challenged recently, but it appears probable that there is such an effect in certain individuals, and that in consequence smoking is undesirable Provided the limb is dry within its coverings, alcohol as a peripheral vasodilator would not seem to be contraindicated, but if the foot is wet the heat loss is accelerated, and once the condition has arisen vasodilators are definitely contraindicated

To maintain the general heat of the body the food should be ample and of good calorific value It should consist of a sufficiency of carbohydrate to provide a ready and easy source of heat, and of fat to maintain the fuel supply when the carbohydrate is exhausted The high fat content of the foods which dwellers in Arctic regions, *e g*, the Esquimaux, have learned to consume has its obvious implications, and these have been followed in many polar and mountaineering expeditions with great advantage The vitamin content of the food requires attention, for, as shown above, an adequate supply of C is essential Possibly the A and P (if this be considered a separate entity) vitamins also play their part in prevention Except in the case of aviators artificial sources of heat, electrical clothing, chemical heaters, etc, are of course impracticable

In cold trench warfare foot drills should be established and carried out at least daily Working in pairs, each man removes his mate's boots and socks, and after washing the feet, when desirable (although this must not be thorough enough to remove the natural grease of the skin), they are inspected for minor abrasions or the first signs of any colour change or swelling The feet are then gently rubbed with whale oil until good absorption has occurred, and clean dry socks and dry boots are again donned It is stated that the quantity of oil thus needed is about 10 gals a day per battalion

There is no doubt that by the adoption of such measures the majority of cases of trench foot can be avoided, but on occasions conditions may be so difficult that prevention proves impossible Wounded men, especially those who have lost blood, are particularly liable to attack, so that, if feasible, they should be removed from the provocative conditions as soon as possible

Clinical course—The onset of trench foot is not always recognized by the victim, for although the initial exposure may produce uncomfortable sensations of coldness on the surface, as the deeper tissues are chilled the nerves are involved and the parts become relatively insensitive This is not always the case, however, and some complain of great discomfort throughout The pain of chilling is not to be compared in intensity with that of the subsequent thaw In this numb state small traumata, which may have serious consequences later, will pass unnoticed—an additional reason for regular foot inspections With a rise in the temperature, or removal from the

causative conditions when a spell of duty is over the first signs of the trouble reveal themselves in swelling with a dusky blue pallor followed later by an intense flush This is the stage of maximum pain and also the stage at which most harm can be done by wrongful handling of the case If of slight severity the swelling persists for several days and then commences to subside with a concurrent change of the colour to normal The surface layers of the epidermis desquamate and peel off paræsthesiæ are complained of and may remain for a time In severer cases the swelling is more marked so that the whole foot may resemble a shapeless pudding blisters form and especially in pressure areas portions of the skin become gangrenous to the uninitiated it appears that the whole foot is doomed These cases are so prone to secondary infection that in the last war it was thought by some that the condition was primarily an infective one In particular fungoid organisms were isolated (Raymond and Parisot) both from the tissues and the mud of the trenches but all types of secondary infecting organisms could be found if the case did not come under control until a surface lesion was already present Such secondary infections often have a great influence on the outcome of the case In the absence of complications a foot in this condition may ultimately recover after a prolonged period and with some superficial loss of skin

In the most severe cases the foot rapidly becomes a dark blue colour and swelling extends upwards to the leg One or more toes may become black and gangrenous In cases of immersion foot the circumstances of production *e.g* water logged boats etc are likely to persist for much longer periods than the exposures in trench warfare In consequence the deeper tissues are involved and the subsequent gangrene affects the whole foot Amputation through the leg is thus a common result and as the condition is almost always bilateral both feet may be lost Even so it must be recalled that the condition looks worse than it is for if the foot is saved it is often found that the gangrene of the toes is only skin deep and that the deeper structures are still alive When the gangrenous portions separate the raw areas remaining are comparable with those left after a burn of corresponding severity and need similar treatment Severe cases all require a very long time for recovery which is frequently incomplete Thus some anæsthesia or paræsthesiæ may remain permanently the skin is sclerotic white with telangiectases here and there and prone to break down under minimal stress Movements of joints are restricted and the subcutaneous tissues are thin and inelastic The circulation continues to be very poor with a greatly increased sensitivity to cold Owing to the increased sus ceptibility which one attack produces (negative local immunity) even the milder cases are unfitted to withstand similar conditions on a second occasion The occurrence of secondary infection in the earlier stages usually leads to a particularly virulent and widespread inflammation which often necessitates the sacrifice of parts otherwise capable of recovery

TREATMENT

If a man is known to have been exposed to the provocative con ditions the greatest of care must be taken during the thaw period It is

dry by drainage; alternatively, the men can be provided with platforms, duck-boards, etc., to keep them above the water-line. This is particularly important when cold periods are followed by intermittent thaws. Since venous congestion and stagnation predispose, attempts must be made to avoid these; men should not rest with the feet dependant, and especially over the edge of a seat or fire-step; movements of the limbs are to be encouraged, and all tight clothing, such as puttees, prohibited. The relationship of heavy smoking to peripheral vascular spasm has been challenged recently, but it appears probable that there is such an effect in certain individuals, and that in consequence smoking is undesirable. Provided the limb is dry within its coverings, alcohol as a peripheral vasodilator would not seem to be contraindicated, but if the foot is wet the heat loss is accelerated, and once the condition has arisen vasodilators are definitely contraindicated.

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impossible it is better to keep the feet cold until such measures are available It has already been mentioned that antitetanic serum is advisable for those who have not received active immunization

When the thaw is complete and the patient is under control in hospital other measures may be used in an attempt to limit further exudation thus the fluid intake is restricted hypertonic solutions either per rectum or intravenously and diuretics even the mercurials may all be utilized If on careful observation it is thought that the pressure in the tissues is jeopardizing the blood supply several dorsal incisions can be made this must not be attempted unless asepsis can be guaranteed for we have already noted how prone to infection the damaged tissues are Even when no incisions are contemplated it is as well to render the foot as surgically clean as possible for blisters cracks etc may subsequently form portals of entry for organisms Cleaning with methylated ether followed by flavine is the method usually adopted although the dye tends to obscure the colour changes which must be kept under observation biniodide of mercury in spirit is a good substitute but other colourless antiseptics may be used If areas of skin or parts of digits become definitely gangrenous expectant treatment is proper for the damage is commonly superficial and in the absence of infection can be dealt with at a later stage After such areas have separated leaving a raw surface this is treated on the same lines as a burn in the corresponding stage Skin grafting may be necessary but the grafts often fail to take on the devitalized and somewhat ischæmic bed

If there be no infection amputation of the whole foot is rarely required (see however p 543) but the loss of one or more toes is a not uncommon result When the initial stages have passed and the foot has healed the further problem of the after-effects arises for the fibrinous exudate undergoes organization and so the whole skin becomes rigid and inelastic the subcutaneous tissues atrophy the vessels are constricted and intraneural fibrosis produces paræsthesiæ etc Such conditions are treated by various forms of physiotherapy which need not be detailed here It may be pointed out that in the past some ambiguity has arisen on account of the great difference in the methods of treatment employed in the acute stages and in the subsequent effects thus forms of heat treatment infra red radiant heat etc which are of value in the late stage are definitely harmful if applied in the acute period Another example of this ambiguity is the application of sympathectomy to these cases Experimental work clearly shows that anything which increases the blood supply in the early stages is to be avoided and sympathetic denervation certainly does this despite the fact that the capillary lumen is diminished Thus periarterial and other sympathectomies in animals not only failed to prevent the swelling and gangrene induced by cold but in some instances actually made the condition more extensive than in the controls Good results have nevertheless been claimed for sympathectomies especially by French surgeons even in the acute stages It would be wise to limit its application to a few carefully selected cases in the late fibrotic stage it will then be found of undoubted value

Later still amputation of stiff contracted toes may be required and special pads and boots are often necessary to relieve pressure on areas which

almost traditional knowledge that great heat should be avoided and that the thaw should be as gentle as possible Strangely enough, Greene records that this tradition did not extend to the Tibetans on the Everest Expedition, who had to be forcibly restrained from roasting or boiling their frost-bitten feet Unfortunately, it is not possible to lay down dogmatic rules owing to the tremendous variation of circumstance and of individual reaction As the circulation returns and the capillaries dilate, exudation is bound to occur, but it would appear that the more gradual transudation of a gentle thaw allows time for some accommodation, while a rapid transudation might produce such local pressure as would determine necrosis At the same time, the curve shown in Fig 411 indicates that in the vicinity of 15° C metabolites may be at their maximum rate of production and therefore that this temperature zone should be passed through fairly quickly The real difficulty is that degrees of surface heat which would cause the deeper tissues to pass rapidly through this zone would be sufficient to produce damage to the skin layers It is clear that there is some conflict of aims here, and as practical experience shows that a slow rate of thaw over the whole temperature range gives better results it is better to adopt this policy Once the part has been withdrawn from the provocative surroundings it is probably best to let the inflowing circulation do the warming without any artificial aid The body heat should, of course, be increased by hot drinks and food

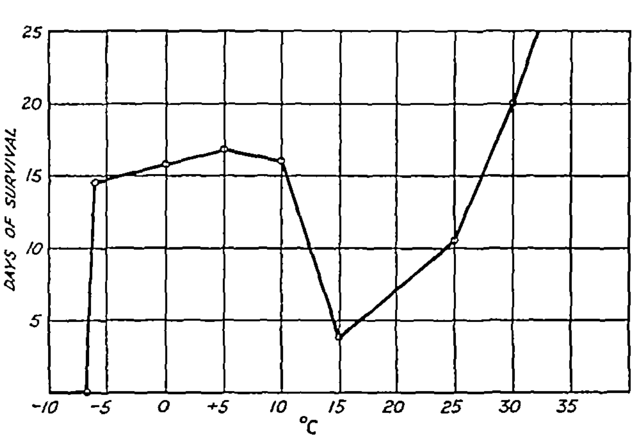

FIG 411

Curve showing the survival periods of tissues stored at various temperatures For a suggested explanation of the dip between 25° and 10° C see text

It will be noted from the experimental work that there were three chief ways in which serious effects could be avoided in animals—one was the local use of vasoconstrictors, the second was multiple incisions to drain away the exudate, and the third (and most successful) was tying the main artery to the limb Clearly these are not all applicable to human cases, but the underlying principles should receive attention To prevent or limit the exudation must be the main aim, and any method directed to this end, whether orthodox or not, is worthy of trial Raising the limb is a simple and easy means of helping which should be adopted from the onset To have any effect upon the capillary pressure the elevation must be considerable, a slight tilt to the bed is of no value The exhibition of peripheral vasoconstrictors, such as adrenalin and ephedrin, during and after the thaw appears logical—the number of cases thus tried in the last war was too small to enable any definite conclusions to be drawn — certainly vasodilators, alcohol, etc, must be forbidden The effects of calcium and of vitamins C and P upon capillary permeability should be utilized As the greatest exudation occurs during the thaw period any treatment must be instituted immediately if this is

The number of cases of immersion foot now encountered is quite large so that the condition demands serious attention (see pp 541 and 543)

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are prone to break down and cause pain under the ordinary stresses of locomotion

The nervous effects require time for their recovery, which may never be perfect In some cases a neurotic element shrouds the actual organic change It may be mentioned, too, that men, hearing of the effect of restriction of the circulation, have been known to tie tight bands, puttees, etc around the legs with the intention of inducing trench foot and so escaping further service

SHELTER FOOT AND IMMERSION FOOT

In the present war two other conditions have been described which probably bear some relationship to trench foot "Shelter foot" is described

Fig 412

Case of bilateral immersion foot, six weeks after exposure for seven days in an open boat in icy weather The gangrene involved the whole thickness of the foot and double amputation below the knee was necessary (*Photo, L MacLellan*)

by Knight as occurring in people who spend nights in cold and oft-times damp shelters with the legs dependant over a sharp edge Greene investigated some of these cases and showed that they usually affected patients showing some evidence of increased capillary permeability associated with a deficiency of the C and P vitamins Since cold appeared to be but a contributing factor these cases are not quite the same thing as trench foot, although some of the factors, such as venous stagnation and increased permeability, may be common to both The second condition is "immersion foot," which is observed in the shipwrecked who spend a long time in water-logged boats or on rafts Here, again, we may have the additional factors of malnutrition and debility with their corresponding vitamin deficiencies arising, but essentially the condition is due to cold and is therefore similar to trench foot

SECTION XI

PERIPHERAL NERVE INJURIES AND WOUNDS OF TENDONS

CHAPTER III

INJURIES OF THE PERIPHERAL NERVES

DURING the 1914 18 war thousands of cases of injury to peripheral nerves occurred, and as a result the pathology and treatment of these lesions was established on a sound basis. Since that time there have been important additions to our knowledge and the frequency with which these injuries occur in war time stimulates interest in this branch of surgery

The best results are obtained when a neurologist and a surgeon co-operate In addition there should be facilities for physiotherapy and a good follow up system.

CHANGES OCCURRING IN A NERVE AFTER INJURY

Changes occurring after division—(*a*) The most striking change Wallerian degeneration occurs in the nerve distal to the lesion (the peripheral stump) The axis cylinders degenerate At the same time there is fragmentation and absorption of the myelin sheaths and a most striking proliferation of the neurilemmal cells of Schwann The neurilemmal cells multiply and form columns which functionally at any rate behave as guiding tubes when regeneration occurs The gross changes are not so striking as the microscopical. Apart from losing its pearly tint the peripheral stump shows no colour change It may become slightly firmer to the touch a moderate diminution in girth is invariable but even in the absence of regeneration the bundles remain recognizable for at least six years after the injury The practical point to be borne in mind is that it is impossible to tell by inspection and palpation whether a nerve trunk is degenerate or not The proliferation of Schwann cells is particularly noticeable at the cut surface of the nerve where they may form a globular swelling slightly larger than the peripheral stump itself and aptly described as the peripheral *glioma* (Figs 413 and 414)

(*b*) On the central side there is retrograde degeneration for at least a centimetre over a rather greater length there are perineural inflammatory changes which soon lead to fibrosis of the sheath the extent of these changes depending on the severity of the original injury and the presence or otherwise of sepsis There are also changes in the anterior horn (motor) and dorsal root ganglion (sensory) nerve cells which we need not consider here After a period of not less than ten days the central stump recovers from the immediate effects of the injury and the severed axons begin to bud at the level where retrograde degeneration ceases that is a centimetre or two proximal to the cut surface Each axon sends out a number of sprouts perhaps as many as five and they spread out centrifugally though most of them seem to be going in search of the peripheral stump If the gap to be crossed is only a small one a number of axons may succeed in entering the Schwann-cell tubes and a certain amount of regeneration follows This budding of the axons often produces a globular mass the proximal *neuroma* that may be two or three times the diameter of the central stump

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(Figs 413 and 414) It is often palpable beneath the skin and, as might be expected, is sometimes tender The characteristic gross lesion, therefore consists of a proximal neuroma and a peripheral glioma They may be united by more or less scar tissue, which is sometimes so extensive that neither swelling can be recognized, indeed, the scar may so mislead the surgeon that he cannot tell whether a complete division is in fact present

Changes after suture—About ten days after a divided nerve has been sutured, axons bud out from the central stump, but this time they should be able to grow down into the peripheral stump without hindrance Simultaneously there is a proliferation of Schwann cells from the peripheral cut surface, exactly like the proliferation that produces the glioma after complete division which quickly closes any small gap that may have been present immediately after the operation Invariably there is much criss-crossing of fibres as they traverse the operation scar, but if the suture has been carried out accurately this disarrangement is local and occurs chiefly between the cut surfaces of apposed bundles Axon buds grow into any convenient Schwann-cell tubes and there is no distinction between the behaviour of motor and sensory sprouts a motor axon may grow into a Schwann tube connected with a sense organ and vice versa One axon sending out several sprouts may innervate more than one Schwann tube, others wander laterally at the suture line, producing a slight thickening that may remain tender for many months However, most of the superfluous sprouts atrophy and disappear All this axonal confusion which up to a point is unavoidable, means that " perfect " recovery can never occur after nerve suture, and the higher the functions subserved by a nerve (the median is the best example) the more apparent the imperfection The growing tip of the axon is unmyelinated, but the formation of a myelin sheath quickly follows and with it is restored the ability of the fibre to re-establish a functional connection with an appropriate motor or sensory end-organ The rate of regeneration is variously estimated, figures varying between 1 and 2 5 mm a day but there are many aspects of this problem that are still obscure and in need of elucidation As a rough working rule it is safe to regard these figures as approximate lower and upper limits

Intraneural plexuses—Although a peripheral nerve is made up of bundles the arrangement of them changes several times before the main trunk breaks up into its terminal branches At certain points, especially a few centimetres proximal to the origin of branches, the rearrangement of bundles is often quite elaborate, so that an intraneural plexus is formed. A severe injury may involve a nerve at or near a zone of internal anastomosis and a subsequent resection and suture is almost certain to bring together surfaces at which there is only imperfect funicular correspondence, however meticulous the operative technique This is an additional reason why functional recovery is often so imperfect

Changes after a lesion in continuity—Sometimes it happens that a peripheral nerve is damaged severely enough to cause degeneration, and yet the supporting structures (endoneurium, perineurium and epineurium) are to some extent spared Although there may be some intraneural scarring, there is no gap or dense zone of scar tissue such as occurs after division, and therefore no *separate* development of central neuroma and peripheral glioma Yet in every other respect the degenerative changes are the same as after complete division, and when regeneration begins the behaviour of the axons is the same Sprouts grow out from the central stump, which swells

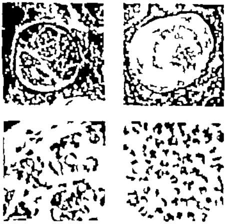
FIG. 413

Complete division of median and ulnar nerves at the wrist. Central neuromas on the right; peripheral gliomas on the left. (Untouched photograph taken at operation.)

Longitudinal section of material removed at operation.

Peripheral glioma Scar Central neuroma

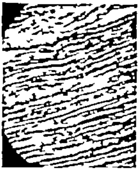
Longitudinal section. These sections show abundant Schwann cells forming tubes waiting to receive new fibres; the deep staining of the low power transverse sections is due to the presence of these cells.



Transverse sections. Transverse sections.

Above: Low power. Above: Low power.

Below: High power. Below: High power.



Longitudinal section. Nerve fibres clearly shown; the abundance of Schwann cells is the result of previous retrograde degeneration.

(I am indebted to Mr J. Z. Young for these micro-photographs.)

FIG. 414

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of the nerve trunk or a lesion in continuity Nevertheless it is often possible to make a shrewd guess for example the chances are that an injury of the radial nerve produced by a fracture of the humerus is due to a lesion in continuity whereas a gunshot wound shattering the humerus has probably divided the nerve But apart from this there are but two methods of finding out—either to wait for evidence of re covery or to explore and inspect the nerve

Fig 416

Partial division of the median nerve; central neuroma on right (Untouched photograph taken at operation.)

An incomplete lesion—An incomplete lesion is present when certain muscles supplied by the damaged nerve escape complete paralysis or when sensory loss is only partial If part of a nerve has escaped serious damage it is unlikely that the remainder has been grossly disrupted As Fig 416 shows this is not invariably the case and if recovery does not ensue fairly quickly exploration is indicated

Syndrome of recovery—It is perhaps necessary to say something about the syndrome of recovery if only to distinguish it from the clinical picture presented by an incomplete lesion. If the history of the case is accurate no confusion should arise Unfortunately clinical notes are sometimes defective and it may be difficult to differentiate between a lesion that was, and still is, incomplete and one that was complete but i now recovering The following table is helpful in this respect

	RECOVERING LESION	INCOMPLETE LESION
Motor—		
	Generally proceeds in an orderly anatomical fashion from the centre to the periphery: proximal muscles strong intermediate muscles weaker peripheral muscles perhaps completely paralysed.	Often a patchy paralysis or a paresis of many muscles not fitting into the picture of orderly central peripheral regeneration.
	Electrical reactions—Response to percutaneous faradism usually lags behind return of voluntary power—but an unreliable sign particularly in the intrinsic muscles of the hand.	*Electrical reactions*—All working muscles respond to f radism.
Sensory—		
	Recovery progresses in an orderly anatomical fashion with return of pain often many centimetres ahead of touch, *e.g.*, if a case with an ulnar nerve lesion in the mid forearm shows about equal degrees of sensibility in both dorsal and palmar areas, then it is likely though not certain that the lesion is a recovering rather than an incomplete one	Reliance can be placed only on relation of one area of sensory loss with another *e.g.*, if a case with an ulnar nerve lesion in the mid forearm shows partial sensory loss in the area supplied by the dorsal branch and complete loss in the palm, then the lesion is probably incomplete

TINEL'S SIGN—Our experience entirely confirms Stookey's (1919) demonstration of the unreliability of this sign In considering the pros and cons of exploration, a positive Tinel's sign alone should never weigh against operation.

Irritative lesions—Irritative lesions causing that most distressing condition known as *causalgia* are the bugbear of peripheral nerve surgery In every case the lesion is incomplete and the nerve involved is usually the median or tibial. Unfortunately we have as yet very little knowledge of the factors responsible for the constant irritation that produces the pain The picture of the fully developed condition is unmistakable The patient is in constant

to form a "neuroma," and the proliferation of Schwann cells at the upper end of the peripheral stump also produces a "glioma" swelling But as the gap between the central and peripheral stumps is nothing more than a break in the axons, the two swellings are fused into one *fusiform enlargement* or *neuroma* which is the characteristic feature of what we have found it convenient to call "a lesion in continuity" Regeneration usually occurs spontaneously, and it now seems certain (Young *et al*), though the reason is not yet evident, that the rate of regeneration after such a lesion is faster than after division and suture Recovery is also better from the functional standpoint, because preservation of the architecture of the nerve ensures that most of the axons regenerate into the appropriate peripheral Schwann-cell tubes A lesion in continuity is most easily produced experimentally by crushing of a nerve with a hæmostat and is best seen clinically in fractures of the humerus that have involved the radial nerve (Fig 415)

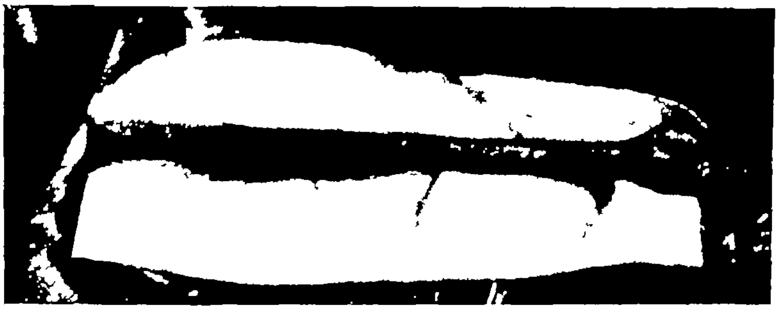

FIG 415

A typical fusiform neuroma, lesion in continuity of radial nerve (Unretouched photograph taken at operation)

Transient block—It is common knowledge that a transient paralysis lasting hours, days, or at the most a week or two, may follow compression or "concussion" of a nerve The paralysis is usually incomplete, the motor disturbance being apparently greater than the sensory, and recovery is so rapid that it cannot be explained in terms of regeneration following degeneration The pathology of these lesions is unknown, but the process is probably comparable with that occurring after the intraneural injection of a local anæsthetic or the short-lived toxic neuritis of diphtheria

CLINICAL INVESTIGATION

There are four well-defined clinical types of paralysis

1 *Complete* = (*a*) Division
(*b*) Lesion in continuity
2 *Incomplete* = (*a*) Division or lesion in continuity with integrity of some fibres, or a transient block of some fibres
(*b*) Transient block
3 *Irritative* (causalgia) = Incomplete lesion plus unknown irritative factor
4 *Functional* = No correspondence with any known organic lesion

A complete lesion—Here there is complete motor paralysis and loss of sensibility in the distribution of the nerve On clinical grounds it is quite impossible to be certain whether this syndrome indicates a complete division

of the nerve trunk or a lesion in continuity Nevertheless it is often possible to make a shrewd guess for example the chances are that an injury of the radial nerve produced by a fracture of the humerus is due to a lesion in continuity whereas a gunshot wound shattering the humerus has probably divided the nerve But apart from this there are but two methods of finding out—either to wait for evidence of recovery or to explore and inspect the nerve

FIG 410

Partial division of the median nerve central neuroma on right (Untouched photograph taken at operation.)

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misery, for the pain never ceases Any sudden stimulus, e g, the banging of a door, aggravates the pain If the arm is affected he protects it jealously, often wrapping it in a wet towel, for cold often eases the pain Thorough examination is impossible, since the gentlest stimulus increases the pain The skin is shiny and often red, warmer than on the normal side and exquisitely tender The nails show trophic changes Difficulty will be experienced in assessing the relatively more frequent cases in which some of these features are present in moderate degree, but it is not unreasonable to suppose that there are grades of irritation There are two features common to them all (1) pain, more or less constant, and occurring in the absence of an obvious stimulus, and (2) some degree of emotional disturbance

Irritative lesions may appear at the time of the original injury or develop days or weeks later Some subside spontaneously those that do not present a therapeutic problem of the first magnitude I have seen ten cases, six of which recovered without operation

Functional—I mention hysterical paralysis only because a number of cases have been sent to me in the belief that they were due to organic lesions A diagnosis of hysterical paralysis can be made with confidence when thorough clinical examination reveals motor paralysis or sensory loss that cannot possibly be explained on any organic basis This should present no difficulty

CASE-TAKING

The method of examination set out below applies to cases in which there is no need for haste Where there are other injuries demanding urgent attention, the clinician will be less thorough in his investigation However, it cannot be urged too strongly that a search for evidence of nerve injury should be made in every case of damage to a limb Too often a cut at the wrist has been sutured and a concomitant median nerve paralysis overlooked, a dislocation of the shoulder has been reduced without any note being made of the presence or absence of paralysis of the upper limb

History—The *type of injury* is important The majority of nerve lesions are due to one of the following causes —

(a) *Traction, e g*, forcible depression of the shoulder, producing a tear of the brachial plexus, stretching or rupture of the peroneal nerve due to an adduction injury of the knee

(b) *Direct blunt trauma* which usually takes the form of compression, *e g*, damage to the musculo-spiral (syn radial) nerve in a fracture of the shaft of the humerus, pressure on the peroneal (syn external popliteal) nerve at the neck of the fibula by plaster, severe cases of tourniquet paralysis

(c) *Open wounds*—Although broken glass and sharp instruments produce examples of these injuries in peace time, nerve lesions due to wounds are essentially war injuries

The examiner should determine the date of *onset of paralysis* in relation to the injury, for occasionally the nerve is damaged in the course of the surgical treatment Detailed inquiry should be made about the *onset of pain* in relation to the injury, this is of special interest in irritative lesions Inquiries about *loss of sensibility* and *loss of power* are always worth while, for they may lead to the discovery that a certain amount of spontaneous

improvement has been noted by the patient but care must be taken to exclude recovery due to overlapping of adjacent nerves The only true evidence of recovery is that found within the autonomous zone of the nerve concerned

Clinical examination—The character of the *wound* should be noted A determination of the line joining the wounds of entry and exit may not only be the best guide to the level of the lesion but may lead the examiner to make a more thorough investigation of nerves that otherwise might have escaped attention A patient with a through-and through wound of the leg may have an obvious foot-drop he may also have a much less obvious lesion of the posterior tibial nerve with anæsthesia of the sole that the patient himself had not noticed but which would ultimately prove far more serious than the noticeable paralysis of the extensors of the foot Where a limb has been peppered with foreign bodies the examination of *scars* may provide the most entertaining detective work before the level of a nerve lesion is identified A search should always be made for a *neuroma* It is an infallible indication of a nerve lesion and in most cases means complete or partial division *Muscle wasting* is to be noted particularly in the hand

FIG 417
Complete median paralysis, but flexion of the thumb is possible because flexor brevis pollicis is supplied by the ulnar nerve

Motor examination—Each muscle in the affected limb should be examined in turn and the power compared with that on the normal side A system of muscle charting makes for accuracy of recording and is a great saving of time The system shown in the chart (p 559) is that recommended by the Peripheral Nerve Injuries Committee of the Medical Research Council and works admirably The examiner must be on the watch for trick movements although skill in their detection comes only as a result of long practice it is a safe rule to pay attention not to the presence or absence of a particular movement but rather to the presence or absence of contraction in the muscles concerned Flexion of the wrist can be produced by any of the common flexors only inspection and palpation of individual muscles and their tendons will show which in fact are producing the movement If all the flexors of the wrist are paralysed (complete median and ulnar paralysis) moderately powerful flexion may be produced by an intact abductor pollicis longus. Abnormalities of innervation are fortunately rare but one must be noted. In many cases the flexor brevis pollicis (Fig 417) is innervated by the ulnar nerve and escapes when the median is completely divided In this case electrical stimulation of the ulnar nerve invariably supplies the answer

For all practical purposes *electrical testing* with galvanic and faradic currents is sufficient No time should be wasted on electrical testing in limbs that are œdematous or where the skin is hard and scaly after a period of confinement in plaster the results will be misleading It is far better to wait until the nutrition of the limb has been rendered reasonably good by physical treatment The basis of electrical testing is simple An intact

nerve will respond to stimuli of rapid frequency, such as those supplied by the faradic coil A muscle with its nerve supply intact will also respond because it receives stimuli through the normal nerve fibres distributed throughout its substance A degenerate nerve will not respond to any form of electrical stimulus A degenerate muscle will, but only to infrequent stimuli, so that the discharges from a faradic coil fail to elicit any contraction On the other hand, the infrequent make and break of the galvanic current produce a slow, rather lazy contraction of the degenerate muscle fibres

THE REACTION OF DEGENERATION consists in the absence of a response to faradism and the presence of a response to galvanism For certain physical reasons, now well understood, the differences between anodal and kathodal contractions are no longer regarded as important Absence of a response to galvanism indicates that the muscle is destroyed and that, even if re-innervation occurs, no return of contractility can be expected

The order of examination should be as follows —

(*a*) The examiner may use bipolar stimulation or a single small electrode for stimulating with the large indifferent electrode bound to the limb some distance away

(*b*) Before applying the stimulating electrode direct to the limb the examiner should interpose his hand to make certain that the current used is not one of painful intensity

(*c*) The stimulus should be applied near the "motor point," the point at which the nerve enters the muscle Those unfamiliar with these points will find it necessary to consult the diagrams given in larger works dealing with this subject The suspected muscles should be examined in turn and their responses noted on the chart

It is sufficient to record the absence or presence of faradic response A faradic response present ten days or more after the date of injury in a muscle showing no voluntary contraction is an almost certain indication either of hysteria or of a transient block

(*d*) Galvanic stimulation need be applied only to muscles that have failed to respond to faradism Here it is most important that the examiner should test the strength of the current, for the sensations aroused by galvanism are distinctly unpleasant It should be remembered that galvanism is applied to muscles and not to their nerves at the point of entry Here again responses should be recorded on the chart

When this has been done the examiner has a complete picture of the extent and degree of motor involvement

Sensory examination—Both the patient and the examiner must be fresh and alert and the examination should be conducted in a quiet room free from disturbance First, the patient should be asked to outline with his finger what he considers to be the zone of abnormality, and he will sometimes indicate areas that might otherwise have escaped detection The examiner then determines the area of loss to touch (anæsthesia), and he may use either cotton-wool, a camel's hair brush or a 1-gm von Frey's hair I have found the brush and the hair equally reliable, and a simple holder for the latter

PARTIAL DIVISION OF RADIAL NERVE, PROVED AT OPERATION WITH COMPLETE PARALYSIS

Name William A. Date	28/3/41			2/6/41	23/6/41	10/7/41	31/7/41	18/9/41	9/10/41	30/10/41
Type of Contraction	Vol.	Far	Gal.	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.
Brachioradialis				1	1 3		3	4	4	5
E. C. Rad. L.					1	3	3	4	4	4
E. C. Rad. B.						0	2	3	4	4
Supinator						2	2	2	4	4
E. Com. D						0	0	2	3	3 3
E. Min. D	0	0	+	0	0	0	0		3	3 5
E. C. Uln.						0	0	0	2	3
Abd. P. L.						0	0	0	2	3
E. P. L.						0	0	0	0	1
E. P. B.						0	0	0	0	0
E. Indic.						0	0	0	0	1
Pron. Teres										
F. C. Rad.										
Palm. L.										
F. D. Subl.										
F. P. L.										
F. D. Prof. (lat.)										
Pron. Quad.										
Abd. P. B.										
Opp. P.										
F. P. B.										
Lumbricals (lat.)										
F. C. Uln.										
F. D. Prof. (med.)										
Abd. Min. D										
Opp. Min. D										
F. Brevis Min. D	3									
D. Interossei										
P. Interossei										
Lumbricals (med.)										
Add. P.										

This chart shows progressive recovery in anatomical order
5 = Normal power
4 = Power short of normal, but contraction against gravity and resistance
3 = Contraction against gravity but not against resistance
2 = Contraction, but not against gravity
1 = Flicker
0 = Total paralysis

can be made either of wood or (as at the Oxford Centre) the end of a bicycle spoke (Fig 418) it carries a horsehair that bends when applied to the pan of a balance against a weight of 1 gm The examiner should work from the anaesthetic to the normal area and the patient be asked to say Yes the moment he feels a definite touch Until it has been established that the patient is a good witness every point should be checked before a mark is made on the skin When the zone has been mapped out all the points should be joined by an ink or pencil line

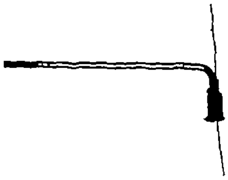


FIG. 418

von Frey hair Graham Weddell's Model horsehair mounted on bent bicycle spoke

Next the patient should be examined with a sharp surgical needle for loss of sensibility to pain (analgesia) The stimulus is first applied to normal skin so that the patient can say at what depth of prick the sensation of pain is distinct without being too unpleasant Here again the examiner

works from the analgesic to the normal zone, and, generally speaking, there is little need to check his replies since the response to a painful stimulus is unmistakable The zone of analgesia should be marked out by a series of dots which are left as such , a zone of analgesia, unlike that of anæsthesia, never has a well-defined border In peripheral nerve lesions it has a fairly constant relation with the more clearly demarcated zone of anæsthesia , the typical picture of loss of sensibility due to a complete peripheral nerve lesion is one of sharply defined anæsthesia containing a slightly smaller zone of less well-demarcated analgesia (Fig 419, A and B) This dissociation of sensibility has an anatomical basis which depends partly on the relative size of touch and pain nerve endings (Woollard *et al*), and perhaps on the relative size of areas supplied by sensory units (Tower) Within the anæsthetic zone there is also loss of sensibility to heat and cold and an absence of sweating A most striking and simple method of demonstrating loss of sweating has been devised by Guttmann (see Fig 419, A to F) The patient, after taking 10 gr of aspirin and drinking two cups of hot tea, is placed in a hot chamber and the part to be examined (in some cases the normal side as well) dusted liberally with a powder having the following composition —

Sodium chinizarin 2-6-disulphonate	35 gm
Powdered sodium bicarbonate	30 ,,
Rice starch	60 ,

Profuse sweating will occur in twenty to forty minutes and is revealed by dark purple staining, the chinizarin dye being very soluble in sweat or water Anhydrotic areas remain light in colour, and after the patient has been removed from the chamber and allowed to dry, the unfixed powder is easily brushed off The stain can be easily washed off with soap and water

It will be noted that Head's terms, *protopathic* and *epicritic* sensibility, have been avoided Head's theory of sensation, an outstanding contribution to neurology, is no longer generally accepted, and the terms he coined, so relevant to the theory, have come to be used rather loosely , many clinicians now regard analgesia as synonymous with loss of protopathic sensibility, and anæsthesia as loss of epicritic sensibility The shorter and more explicit terms are preferable

Two-point discrimination is chiefly of interest during the period of recovery, though it is sometimes of value at an early stage when a minimal lesion of a nerve is suspected In a complete nerve lesion *vibration* and *joint sense* are normally lost within a very small field, for example, at the terminal interphalangeal joint in complete division of the ulnar nerve , their return is one of the earliest indications of recovery

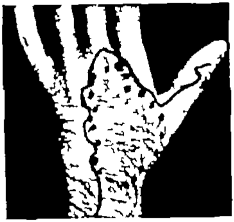
Finally, the examination should conclude with a full account of the state of the bones, joints, muscles and vessels in the affected limb, and a search should be made for trophic disturbances—shininess and ulceration of the skin and abnormal growth of the nails and hair

Radiographic examination must always include the site of the nerve lesion for it may reveal unsuspected foreign bodies

By this time the examiner will have so complete a picture of the lesion that it should be possible for him to make a fairly confident diagnosis He must then decide whether the case is one for immediate exploration or expectant treatment If the latter, then it will be necessary to keep a record of progress which calls for a short examination once a week and

A, Median injury with sparing of most of the ring finger

B Typical lesion of the median nerve



C, Lesion of the superficial radial nerve.

D Lesion of the ulnar nerve

E and F Division of the tibial nerve In this case the wound was just below the head of the fibula.

Fig 419

In every case the line indicates the zone of anaesthesia the dots the zone of analgesia. The dark staining of the skin shows the presence of sweating These cases were investigated by Guttmann s technique

CLINICO-PATHOLOGICAL CLASSIFICATION

Type	Etiology	Anatomical Changes	Histological Changes	Clinical Picture	Recovery	Operative Treatment
Division	(a) Open wounds of all kinds (b) Traction injuries	Neuroma and glioma with a gap of varying length Sometimes as above but often a length of fibrotic nerve containing few nerve elements	Complete Wallerian degeneration	Complete motor and sensory loss: R D in muscles	Rare without suture: mean rate of regeneration 1 to 2 5 mm a day but generally the slower rate proximal to distal progression	Resection and suture
Lesion in continuity	(a) Wounds—"near misses" (b) Pressure (especially fractures) (c) Traction (d) Friction e g., traumatic ulnar neuritis	Fusiform neuroma	Complete Wallerian degeneration but preservation of more or less of supporting tissue of the nerve	Complete motor and sensory loss: R D in muscles	Generally spontaneous and often rapid mean rate 1 5 to 3·0 mm. a day proximal to distal progression	Removal of mechanical obstruction: otherwise leave alone
Transient block	Compression	Not known	Disturbance of axis cylinders short of complete interruption	Motor loss often complete sensory generally incomplete: no R D in muscles	Rapid a matter of days or a few weeks recovery often appearing with equal rapidity throughout the zone of disturbance	None required

a complete examination once a month Some form of splint may be required and physical treatment will be necessary, these matters are discussed later

TREATMENT

Open wounds—When is it safe to suture a nerve in a recent wound?

The majority of incised wounds, if dealt with within the first six hours, may be treated by primary excision and immediate closure in only a few lacerated wounds is such a course permissible *Only in wounds that can be relied on to heal by first intention is nerve suture justifiable*

If the wound is of this kind, what should be done when a fracture is present?

Here everything depends upon the ease with which the fracture can be reduced If the fragments can be controlled with ease and the final position of the limb is one in which suture of the nerve can be carried out with comfort (the nerve suture being the last step in the operation before closure of the wound), then the operation is permissible

Illustrative Cases

Case 1—A medical student was wounded in the left arm during an air raid It was a penetrating wound in the middle of the arm with fracture of the humerus, division of the brachial artery and venæ comites, the basilic and cephalic veins and the ulnar nerve In addition there was median and radial paralysis The patient was operated on (by Mr D H Patey) three and a half hours after the infliction of the injury The wound was excised and the damaged vessels were ligated, the median nerve was seen and found to be intact, the radial nerve was not seen and no search for it was made, the transverse fracture of the mid shaft of the humerus was controlled without difficulty The ulnar nerve was therefore sutured after freshening of the stumps, 10 gm of sulphanilamide were placed in the wound, antitetanus serum was given, and the wound closed around a small drain The operation was carried out early under ideal conditions and the fracture was easily controlled The wound healed by first intention and the fracture united in perfect position

When there is difficulty in the management of the fracture, repair of a divided nerve should not be undertaken

Case 2—A soldier was wounded in the upper third of the right thigh by a rifle bullet that shattered the femur and produced a complete sciatic paralysis This occured at 7 P M, he was admitted to the

Wingfield Morris Hospital at 9 40 P M in a state of shock, and by 10.30 P.M. his condition was sufficiently good to warrant operation

Operation (Mr J C. Scott)—The wound was excised and enlarged all damaged muscle was removed the sciatic nerve was not seen and no search was made for it a dry pack was placed in the wound, a pin inserted through the tibial tuberosities and the limb put up in a Thomas splint with traction. During the course of the operation it was necessary to give 3 pints of plasma. In this case any attempt to repair the nerve would have been folly The patient s condition did not warrant a prolonged operation, and to have placed him on his face would almost certainly have upset the position of the femoral fracture The wound healed in nine weeks by the thirteenth week the fracture was soundly united and there was a satisfactory range of movement at the knee exploration of the sciatic nerve (which revealed a complete division) was then carried out.

If the surgeon considers that suture is permissible he should first perform a thorough excision of the wound the final stage is repair of the nerve The ends of the nerve are irrigated with saline and trimmed this is a surprisingly difficult manœuvre since fresh nerve tissue is soft and slippery and the only instrument that I have found satisfactory is a pair of fine and very sharp scissors Suture is carried out in the usual way (see below) care being taken to ensure that no rotation of the nerve has occurred it should be possible to obtain almost perfect apposition No hesitation need be felt in employing compounds of the sulphonamide group the advantages to be gained in the prevention of infection far outweigh any possible toxic action on the damaged nerves After closure of the wound the limb is placed in plaster with the nerve slightly relaxed Seeing that only a small quantity of nerve tissue has been resected splinting in relaxation need not be maintained for longer than two weeks

The doubtful wound—The surgeon may feel tempted to inspect the nerve so that he may know whether he will have to perform a suture at some future date or whether the discovery of a lesion in continuity will indicate that expectant treatment is the correct course This is only permissible should he encounter the nerve during the course of the operation if it does not appear he should not hunt for it When a divided nerve is discovered nothing whatever should be done to it

HEALED WOUNDS

The majority of nerve suture operations are rightly performed when the wound has healed soundly Under favourable circumstances (sound union of a fracture satisfactory movements in joints) exploration of a nerve may be undertaken about two months after the wound has healed Risk of recrudescence of infection is very slight and with the judicious local and general employment of drugs of the sulphonamide group this is reduced to vanishing point

INDICATIONS AND CONTRAINDICATIONS FOR EXPLORATION

(*A*) **In the presence of signs of complete interruption**—1 If there has been an open wound which has healed soundly and the picture is that of a complete nerve lesion early exploration should be advised Apart from waiting, and perhaps thereby wasting valuable months there is no other way of determining the nature of the lesion

2 If there is a palpable neuroma the probability is that the nerve has been completely severed

3 When the lesion follows a traction injury it is wise to wait and see if spontaneous recovery will occur. Traction injuries are usually associated with diffuse nerve damage not readily amenable to radical repair

4 Nerve injuries accompanying closed fractures generally recover spontaneously Exploration may safely be deferred (treatment of the fracture usually makes this necessary anyway) until after such time as is required for the appearance of the first sign of spontaneous recovery

(*B*) **In the presence of signs of incomplete interruption**—As has been indicated already, the syndrome of incomplete interruption of a nerve is much more suggestive of a partial lesion in continuity than of a complete disruption of part of the nerve trunk It follows therefore, that in most cases a conservative attitude is likely to be correct. On the other hand, apart from waiting to see if recovery will occur spontaneously, there is no method short of operation whereby a partial lesion in continuity may be distinguished from a partial division In Fig 416 an example is given of a partial division in which only surgical repair could afford a prospect of recovery In lesions of the main trunk of the sciatic nerve it is not uncommon to find partial interruption of one division and complete severance of the other—usually the peroneal (see Fig 422)

In the minority of cases—those in which spontaneous recovery does not occur within a reasonable time—the surgeon is justified in performing an exploratory operation What exactly is meant by a reasonable time? This question can best be answered by quoting a relevant case

On 27th May 1940, when a number of shell fragments penetrated the patient's right arm, there was immediate median paralysis, the patient was a doctor and aware of what had happened to him His wounds were correctly treated, and by the end of July they had healed soundly The median nerve was thickened and could be palpated beneath the scar In the months that followed there was slow improvement in the flexor sublimis digitorum, the lateral half of flexor profundus and the flexor longus pollicis The remaining muscles of median innervation in the forearm remained completely paralysed, as did intrinsic muscles of the hand supplied by the median The patient himself noticed little improvement of sensibility, although when examined fourteen months after the injury the sensory loss was that of an incomplete lesion, anæsthesia was confined to the index and ring fingers, the rest of the median area being hypoæsthetic, analgesia was confined to the index and middle fingers

The distance between the wounds and the thenar muscles was 51 cm Taking the low estimate of the rate of regeneration of 1 5 mm a day, there should have been signs of improvement after the 340th day Nevertheless, on the 430th day the thenar muscles were still paralysed On these grounds a diagnosis of partial division of the median nerve was made On 20th September 1941 I exposed the nerve just below the axillary fold and found the lesion shown in Fig 416 a very obvious partial division with conductivity confined to the fine strand

The latter was dissected proximally and distally, and the remainder of the nerve treated by excision of the stumps and suture

Summarizing—Exploratory operations usually yield information concerning the lesion that cannot be obtained in any other way Liberation of a lesion in continuity from scar tissue—neurolysis—may in itself be of value In doubtful cases belonging to this group, Stookey's aphorism is a good one "Radical nerve exploration—conservative nerve operation"

NEUROLYSIS

The value of this operation is still debatable Where a nerve is obviously lying in unfavourable surroundings—the best example being traumatic neuritis of the ulnar nerve resulting from a bone abnormality in the region of the elbow—neurolysis, and in this case transplantation of the nerve anteriorly, is a most rational procedure In general the case for liberation of a nerve from scar tissue has not yet been made out convincingly Dramatic recoveries have been reported, recoveries occurring a comparatively short time after neurolysis, but their significance is less than might be supposed

If the lesion is one that has caused true Wallerian degeneration (and operative intervention ought never to be contemplated unless this is the case) a certain minimal time must elapse before regeneration can occur In some reported cases of recovery following neurolysis the recovery has been so rapid that it could only be explained by regeneration being well advanced at the time of the operation In other word return of function happened to follow the operation it was not due to it

Internal neurolysis implies the removal of scar tissue from within the nerve sheath This is an even more doubtful procedure and if the scar is sufficiently extensive to require drastic treatment a resection and suture is more rational. A milder form of internal neurolysis—longitudinal incision of the nerve sheath—has its advocates, but again they have yet to prove its value

OPERATIVE TECHNIQUE

The description about to be given applies to all nerves and up to a point to exploration and suture alike

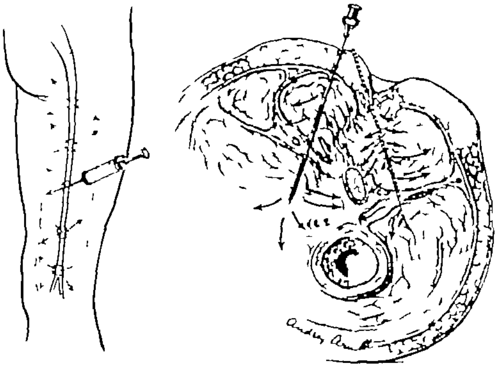


Fig 420

Technique of local infiltration anaesthesia without anaesthetizing the nerve itself.

Preparation—Platt s suggestion that an appropriate plaster cast, made with a limb in the correct post-operative position, should be prepared beforehand is indicated only occasionally It is so difficult to foretell if resection and suture will be necessary and, if it is, what position of the limb will be called for

The skin preparation must be generous

Anaesthesia—If general anaesthesia is employed the anaesthetist should be prepared for a long session and select his anaesthetic accordingly Where wide and deep exploration is required I have found it helpful to combine general anaesthesia with local infiltration of 0 5 per cent procaine and 0 001 per cent adrenalin the procaine should be made up as follows 1 volume of 2 per cent procaine and 3 volumes of normal saline The injection of this solution reduces bleeding and assists the surgeon by separating tissues Unless injected directly into a nerve procaine of this strength has no effect

on conductivity By making the injections well to each side of the nerve the only objection to local infiltration of procaine is obviated

In a large proportion of cases local without general anæsthesia suffices (Fig 420), indeed its employment has an added advantage When the time comes to investigate the conductivity of the nerve, sensory as well as motor observations can be made The solution already described is used and it remains effective for four hours

Exposure[1]—The incision should be a generous one so that there may be no difficulty in identifying the nerve in normal surroundings both proximally and distally Having identified the nerve above and below, the surgeon dissects towards the lesion, particularly when there is much scar tissue patience and gentleness are necessary Strict hæmostasis is essential,

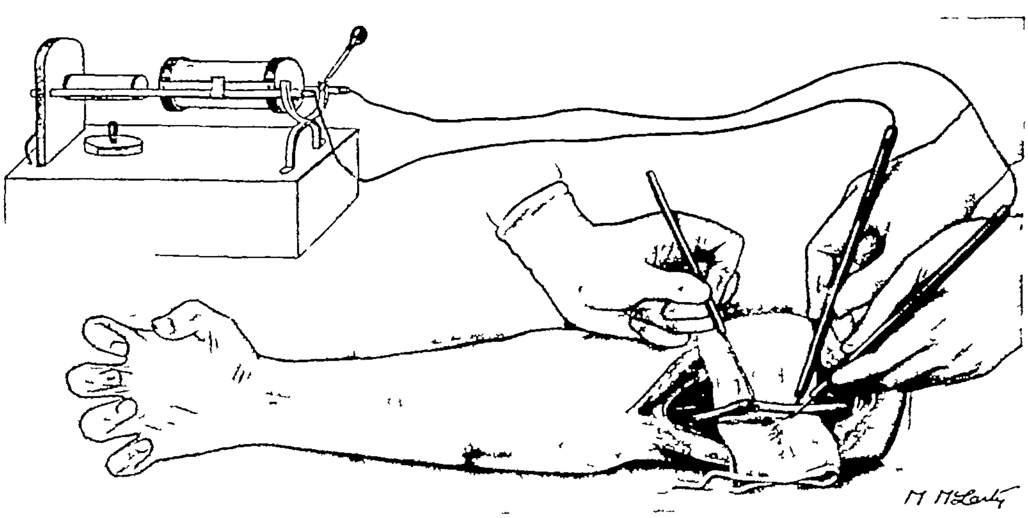


Fig 421
Stimulation of nerve trunk with bipolar faradism

diathermy is helpful in this respect Nothing must be divided until the surgeon is certain that it does not contain a part of the tissue he is seeking to isolate Bipolar faradic electrodes should always be close at hand, for motor nerves buried in scar tissue can often be identified by appropriate stimulation When the nerve has been freed by dissection the exact nature of the lesion must be determined

Complete division, with or without intervening scar tissue, usually presents no difficulty A fusiform neuroma (see Fig 415) is likewise obvious The troublesome cases are those in which there is so much scar tissue that the surgeon cannot tell whether he is dealing with a very fibrous lesion in continuity or with a complete division which his dissection has fashioned into the shape of a fusiform neuroma The steps to be pursued are as follows —

(*a*) Inspection

(*b*) Palpation—Sometimes it is possible to feel a central neuroma that is not obvious to the eye If the scar tissue at the mid-point of the lesion is very hard, then it is likely that the division is a complete one and that resection will be indicated

[1] It is not possible here to describe the anatomical approaches to individual nerves They are available in a number of standard works of which incomparably the best is Sir Harold Stiles s essay in ' Orthopædic Surgery of Injuries Editor Sir Robert Jones 1921 Vol II Oxford Medical Publications

(c) Electrical stimulation.—*Motor* It sometimes happens that although paralysis may be complete clinically and the reaction of degeneration present in all muscles direct faradic stimulation of the nerve either above (Fig 421) or below the lesion will produce a distinct contraction in one or more of the muscles innervated below the level of the lesion In a case of this kind resection and suture should not be performed unless further unravelling of the lesion itself reveals a partial division *Sensory* If the operation is performed under local anæsthesia it may be possible to identify sensory fibres in the peripheral stump by applying the electrodes below the lesion For example a patient with a lesion of the ulnar nerve in the forearm

Fig 422

A difficult operative problem. The sciatic trunk involved in dense scar tissue beneath the gluteus maximus. Lesion found to be partial division of peroneal trunk, and lesion in continuity of the tibial. Suture of peroneal alone

may on peripheral stimulation complain of tingling in the little finger This indicates that fibres have grown down at least as far as the electrodes and that the lesion is not a complete division in some of our cases showing phenomena such as this nothing further has been done to the nerve and spontaneous recovery has followed

(d) Dissection of the lesion is of special importance in injuries of the main sciatic trunk It is usually possible to identify the tibial and peroneal divisions above and below the lesion and by carrying the dissection towards the site of damage it is sometimes feasible to split the sciatic trunk into its components—often with astonishing results One may find the tibial division anatomically intact and therefore probably the site of a lesion in continuity whereas the peroneal division is almost completely interrupted (Fig 422)

(*e*) INJECTION OF NORMAL SALINE—If a fine needle is used, little harm is done by injecting the site of damage with normal saline solution If great resistance is encountered it means that the fibrous tissue is exceedingly dense the probability of the lesion being a complete one is therefore considerable On the other hand, if the nerve is distended easily fibrosis is probably perifascicular and the lesion is one in continuity

(*f*) TRIAL SECTION—If by this time the surgeon is reasonably certain that he is dealing with a complete lesion, section involving one-quarter to one-third of the nerve trunk at the centre of the lesion may be made (Fig 423) If it reveals dense fibrous tissue and no obvious nerve bundles, the incision is deepened Complete section should not be made until guide sutures have been inserted proximally and distally to indicate corresponding points on the circumference of the central and peripheral stumps When the operation is performed under local anæsthesia, *painless* section indicates complete absence of conducting sensory fibres

When in doubt as to whether complete section is justifiable, the surgeon should halt After suitable treatment of the bed of the nerve (see below) and complete control of bleeding, the damaged nerve trunk should be replaced unless it can be transposed to more congenial surroundings, the operation is then brought to a close If after a further period of observation no recovery takes place, re-exploration, resection and suture of the lesion can always be carried out

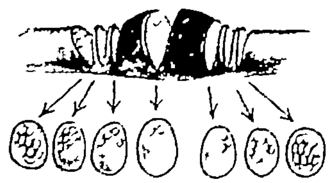


FIG 423
Method of performing trial section

Mobilization—Should it be decided that suture of the nerve is necessary, the next important step is mobilization of the nerve trunk It is certain that a gap of several centimetres will be present after excision of the damaged part of the nerve, and mobilization is necessary in order to obtain satisfactory approximation It is carried out in six distinct stages and *before the nerve section is performed*

(*a*) ADEQUATE EXPOSURE—The incision is enlarged for as far as is necessary for the next step

(*b*) FREEING THE NERVE TRUNK centrally and peripherally should be carried out as far as is possible anatomically This will yield an increase in length of a few centimetres So far as we know, this procedure interferes very little with the blood supply of the nerve, after extensive freeing of the sciatic nerve, bleeding will often be noticed when the central and peripheral stumps are resected

(*c*) FLEXION OF JOINTS is a great help, and in combination with freeing the nerve is generally sufficient to give the additional length required

(*d*) TRANSPLANTATION OF THE NERVE—The best example of this procedure is transplantation of the ulnar nerve to the front of the medial epicondyle of the humerus

(*e*) STRIPPING OF BRANCHES—Branches of peripheral nerves arise several centimetres proximal to the point at which they become obviously separate, and by careful dissection it is often possible to free them and so increase the mobility of one or other stump

(*f*) SACRIFICE OF BRANCHES should not be undertaken unless the surgeon feels sure that the sacrifice is justified

Bone shortening is indicated only in the case of non union of a fracture of the humerus and an extensive lesion of one of the main nerves of the arm —most probably the radial Even in such a case it is usually wise to suture the nerve sometime after the operation for non union

Examples of actual cases will serve best to illustrate how these various manœuvres contribute to the attainment of the only radical operation that has proved its merit in peripheral nerve surgery namely end to-end suture

Example 1—Median nerve lesion in forearm, 10 cm. above medial epicondyle

Freeing nerve proximally gained	2 cm.
Freeing nerve distally gained	2 „
Flexion of elbow to 90 additional	4 „
Flexion of elbow from 90 to 140 additional	2 „
Adduction and int rot of shoulder additional	3 „
	13 cm.

This was for a very extensive lesion.

Example 2—Extensive radial nerve lesion about 4 cm. above the lateral epicondyle the nerve to brachioradialis arising from the peripheral trunk 1 cm below the lesion. It was necessary to provide for the closure of a gap of 3 5 cm., but freeing of the proximal trunk and flexion of the elbow were almost useless because the peripheral stump was tethered down by the branch to brachioradialis. After the sacrifice of this branch, apposition was obtained without tension

Bulb suture—When after mobilization it is estimated that resection and suture cannot be effected or cannot be effected without undue tension bulb suture is an expedient which should be in the forefront of the surgeon's mind it is often strikingly successful The neighbouring joint is flexed and the untrimmed nerve ends are laid side by side with as much overlap as possible though stopping short of overlapping healthy nerve tissue Stout sutures are passed through the bulbs fixing them firmly together and the wound is closed (Fig 424) Gradual extension of the flexed joint produces an elongation of the nerve When full extension has been obtained the lesion is exposed again and it is usually possible to proceed with re section and end to-end suture

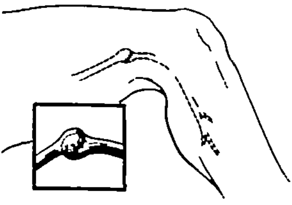


FIG 424
Showing the principles involved in bulb suture

Resection of the stumps—If the operation is being performed under local anæsthesia the proximal trunk should be injected with 2 per cent procaine well above the line of section a very fine needle being used The resection should be as generous as possible so that there may be no great amount of intra neural scarring to obstruct regeneration. The best knife is an ordinary safety razor blade held in a hæmostat (Fig 425) and the first cut should be made at the point nearest the lesion where the nerve is of normal con sistency If the gap to be closed is a large one the surgeon may feel compelled

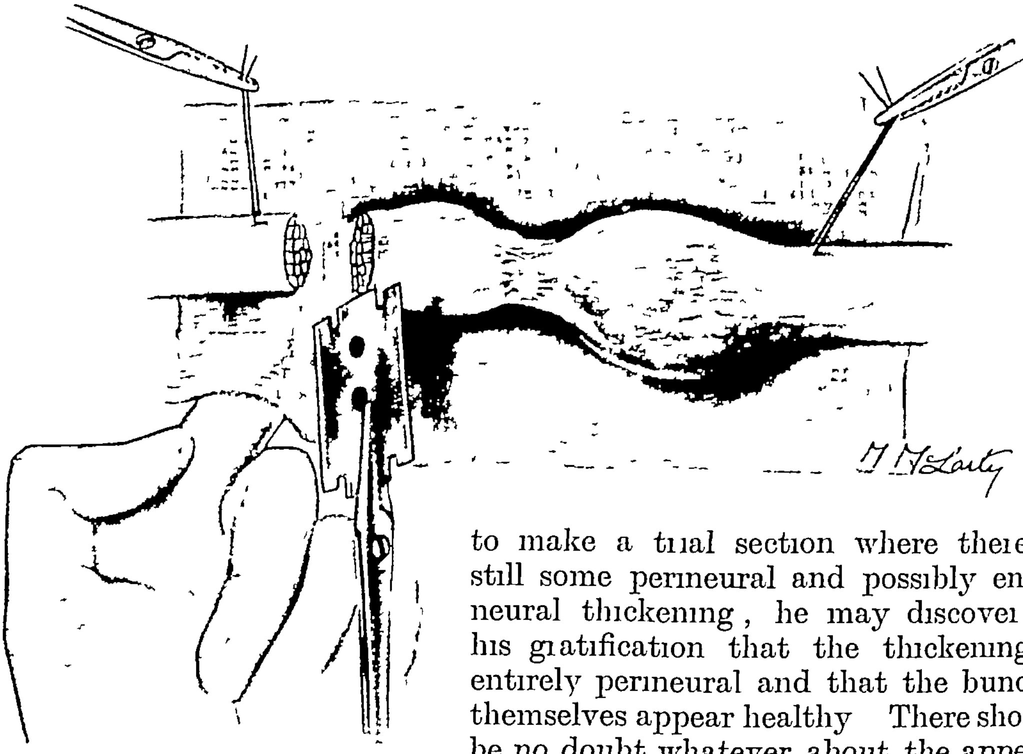


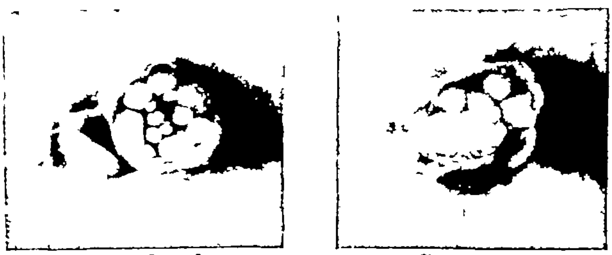
Fig 425
Excision of pathological tissue prior to nerve suture, note healthy appearance of bundles and retractility of the sheath

to make a trial section where there is still some perineural and possibly endoneural thickening, he may discover to his gratification that the thickening is entirely perineural and that the bundles themselves appear healthy There should be no doubt whatever about the appearance of healthy bundles—they stand out in the most obvious way (Fig 426), though the peripheral bundles are not always so distinct as those in the central stump Another indication that the section has been made sufficiently far back is the retractability of the nerve sheath, which, in a normal central or peripheral stump, springs back smartly from the bundles as soon as the section is made

Fig 426
Complete division of the ulnar nerve just proximal to the nerve to flexor profundus digitorum The segment excised

The bed for the sutured nerve—The surgeon is now in a position to see where the suture line will finally lie and the nature of the tissue beneath it Should the bed be an unhealthy mass of scar tissue, three courses are open to him —

(*a*) The nerve may be moved to one side into a new and healthier position the median, for example, when divided in the middle of the arm may be laid deep in the groove between the



Peripheral Central
Fig 427
Note the lack of correspondence between the funiculi The injury damages the nerve at the site of an intraneural plexus This is the same case as is illustrated in Fig 414

brachialis and the biceps The ulnar nerve may be transposed anteriorly

(b) The scar if not too extensive may be excised

(c) The scar may be folded over on itself and sutured so that healthy tissue is presented to the under surface of the sutured nerve

Partial closure of the wound—The incision is almost invariably of considerable length and the proximal and distal parts should be closed before the limb is flexed and suture of the nerve performed If the limb is flexed first and the nerve sutured it may then be found exceedingly difficult to close the skin incision

SUTURE OF THE NERVE

Suture material—The reaction produced by suture material is proportional to its size as well as to its nature The ideal material is one that can be obtained in extremely fine threads of good tensile strength and produces a minimal reaction The majority of surgeons are opposed to catgut because of the brisk cellular reaction that it provokes Fine linen produces only a small reaction Silk can be obtained in even finer threads and provided that it is used plain or dyed with a non irritant substance it induces only a small zone of cellular infiltration and fibrosis An even finer and less irritant material is human hair[1] and for those with the skill and patience to use it it is unquestionably the suture of choice It cannot be employed if there is more than the slightest tension at the suture line though sometimes a combination of fine silk (No 0 Deknatel) and hair will give perfect closure in difficult cases

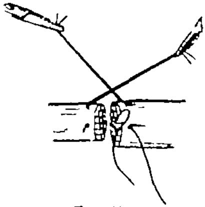


Fig 428

Technique of nerve suture; tension sutures used only for approximation

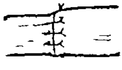
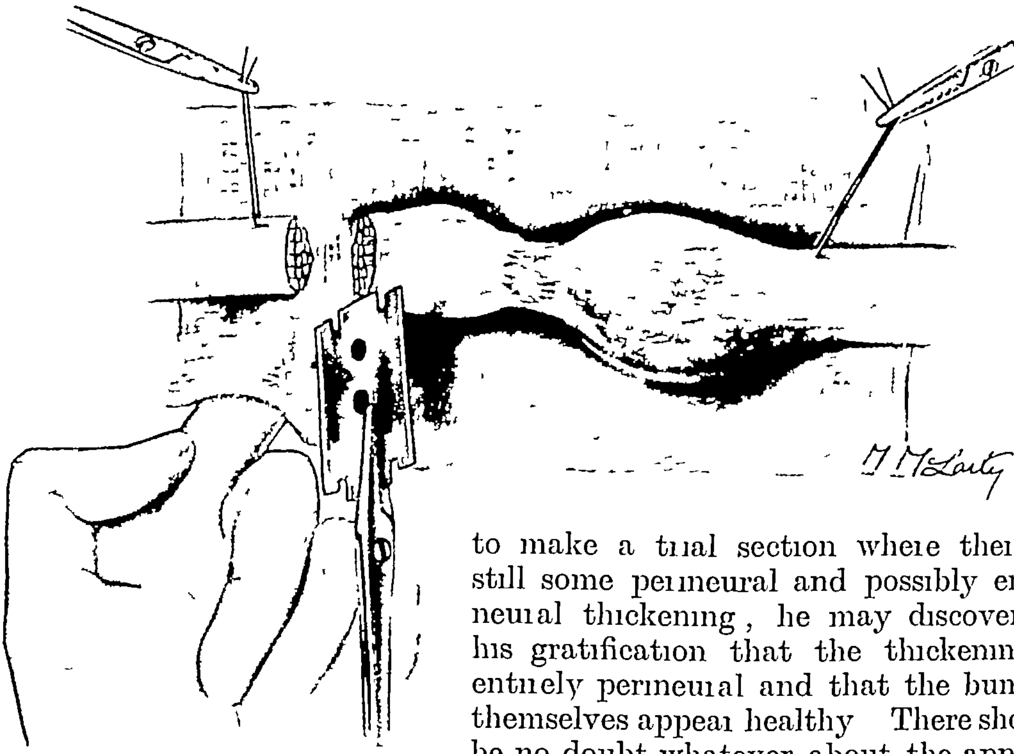


Fig 429

Sutures are tied just tight enough to close the sheath

Under no circumstances should it be necessary to pass any sutures through the substance of the nerve All sutures are passed through the sheath alone (Fig 428) they are interrupted and no more should be employed than are required to complete closure of the sheath (Fig 429) The knots should be tied with great care to avoid the nerve bundles being pressed together If there is to be any defect at the suture line it should be a slight gap rather than a slight crowding for the latter is a certain guarantee of irregular regeneration The first two or three sutures inserted are left long and held with mosquito forceps they are used to rotate the nerve while the remaining sutures are being placed In most cases the central and peripheral trunks are of different diameters and it has been recommended that the peripheral (smaller) trunk should be cut obliquely This is almost a technical impossibility and the surgeon must do the best he can by approximating the sheaths

[1] L. Guttmann—unpublished work.



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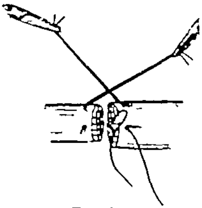

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as accurately as possible When satisfactory apposition has been obtained the guide sutures are withdrawn, the nerve is laid gently in its bed and the wound is closed On no account must the position of the limb be disturbed until complete fixation in plaster has been obtained

The work of Young and Medawar on fibrin suture of nerves (see Chap LXXXII) has attracted considerable attention, and I have used their concentrated plasma on a number of occasions Unfortunately, it is still a laboratory preparation and, because of difficulties in manufacture, not yet available for general use

Post-operative fixation—It is sufficient if plaster slabs and a few turns of bandage are applied to the affected limb, though after a sciatic nerve suture this is not a light undertaking

Post-operative stretching—Except after suture of a freshly divided nerve, where there is no great loss of substance, gradual extension of the limb must be carried out This means nothing less than organic lengthening of the nerve, and it must therefore be a gradual process It has generally been

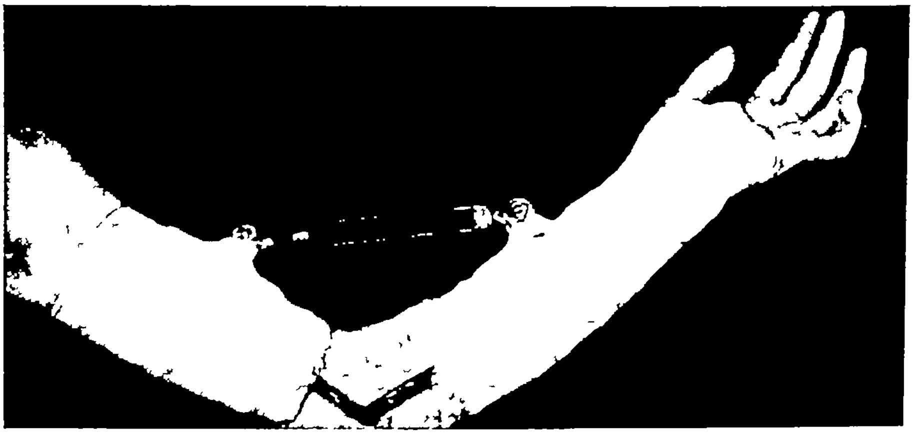

FIG 430
Turnbuckle plaster applied after suture of the ulnar nerve There was a considerable gap which was not made good by anterior transposition alone

the custom to maintain the limb in a flexed position for two or three weeks, this being based on the knowledge that nerve fibres grow across the suture line from the tenth day onward and that the perineural scar tissue, like that after an incision in the skin, becomes reasonably strong after the second week But the time required for stretching a nerve that has lost a certain length of its substance is not precisely known, and the times given to obtain full extension of the limb from the position of 90° or 120° flexion vary from six to ten weeks In the main we have followed the experience of surgeons in the 1914-18 war , preliminary fixation has been maintained for three weeks, and the process of stretching has occupied six or seven, making a total of nine to ten weeks, depending upon the initial degree of flexion In one case where, owing to a faulty plaster, extension occurred rather more rapidly than this, we were so afraid that damage might have been done that I persuaded the patient to allow us to inspect the suture line through a small incision made under local anæsthesia There was a perfect union, and peripheral stimulation demonstrated the presence of sensory fibres well beyond the line of suture If one swallow makes a summer, this case shows

that the times given are at any rate not too short though they may well be too long

The actual stretching process has generally been left to gravity and the patient's own efforts It seems wiser to control it by an articulated plaster (Fig 430) This plaster is hinged at the flexed joint and the rate of extension determined by the unscrewing of a turnbuckle

Nerve grafting—As soon as the surgical repair of peripheral nerves became feasible the problem of bridging large gaps began to engage the attention of surgeons and research workers and to-day the interest it arouses is very great—perhaps because the problem still awaits a final solution Of all the manœuvres designed to bridge a gap that cannot be closed by suture nerve grafting alone survives as a rational and reasonably promising procedure The experimental evidence in favour of nerve grafting is unassailable (Sanders and Young), and notable successes have been achieved in man in repair of the facial nerve (Duel; Collier) and in the hand (Bunnell and Boyes) But these are simple problems compared with the bridging of a gap in a large nerve trunk in a limb, where there is difficulty in obtaining sufficient grafting material and, if it is obtainable the possibility of necrosis occurring in it after implantation. It seems reasonably certain that autografts of normal or predegenerate nerve offer the best chance of success; homografts behave in an irregular fashion and heterografts are useless.

Although hundreds of grafting operations were performed during the last war the reports of useful recovery were depressingly scanty Nevertheless, there is now a brighter prospect of success, for the biological behaviour of grafts is well understood, and the technique of grafting in man is gradually evolving The problem in this war has not yet been one of any magnitude since by thorough mobilization it is generally possible to secure end to-end suture The repair of digital nerves, however presents great possibilities, and those interested are advised to consult Bunnell's excellent papers. The treatment of other peripheral nerve lesions by grafting has not yet been worked out completely

Fig 431

Abduction splint for paralysis of abductors of shoulder

PHYSICAL TREATMENT

(*A*) **Splinting**—Although splinting plays no part whatever in the regeneration of a peripheral nerve it is all important so far as muscle function and the prevention of deformity are concerned An overstretched muscle will not regain its contractility even though its nerve supply may have been restored completely The best form of splint is one that maintains paralysed muscles in a position of moderate relaxation (approximation of origin to insertion) and at the same time permits movement through a small range

Six types of splint are required

1 The abduction splint for *brachial plexus* injuries with paralysis of the deltoid (Fig 431)
2 The knuckle-duster splint—designed by W B Highet This I believe is the only satisfactory splint for *ulnar paralysis* that has yet been devised. It maintains flexion at the metacarpo phalangeal joints and encourages the patient to keep the interphalangeal joints extended. It provides complete protection

against the development of a claw hand, but it must be fitted with great care (Fig 432)

3 After many experiments the splint for *median paralysis*, shown in

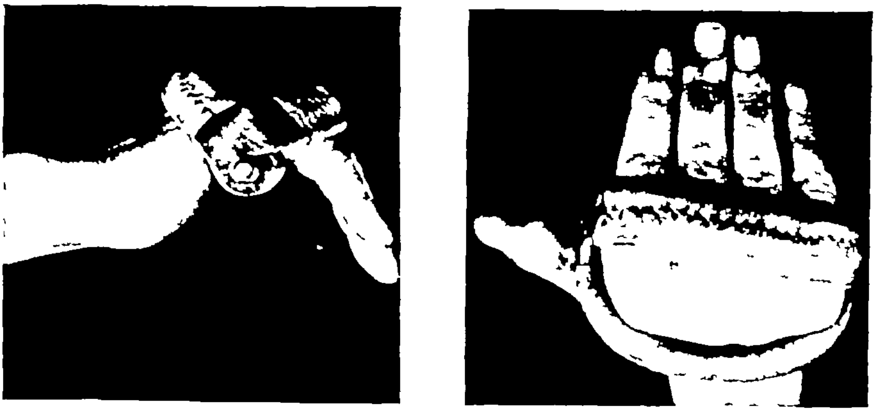

FIG 432

Splint for ulnar paralysis The palmar roller is the same as in splint shown in Fig 434

Fig 433 was devised and so far has proved satisfactory It provides relaxation for all the intrinsic muscles of the thumb

4 Combined *median and ulnar* splint this is an elaboration of the knuckle-duster (Fig 434)

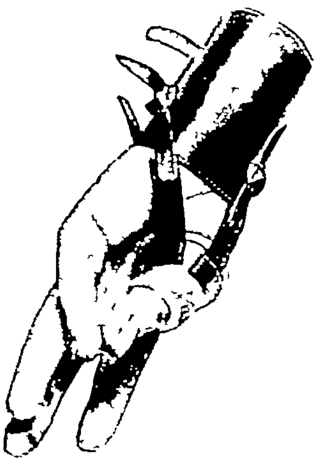

FIG 433

Splint for median paralysis, the cuff for the thumb is made of moulded leather, the proximal edge being everted

5 The *radial paralysis* splint (Fig 435) is that recommended by the Medical Research Council after the last war It has never been bettered though there is no denying that it is elaborate A man wearing this splint may do moderately heavy work without the slightest risk of overstretching any of his paralysed extensor muscles

6 For sciatic paralysis the well-known below-knee steel with a toe-raising spring has proved satisfactory The details of this instrument are sufficiently familiar to make illustration unnecessary

(*B*) **Massage, electrical treatment, movements and exercises**—All patients with nerve injuries require physical treatment

Massage—The application and value of this form of treatment are so well known that they do not call for discussion

Electrical treatment is the bone of contention When a peripheral nerve has been divided, any muscle it supplies begins to waste rapidly, and so far nothing has been discovered that will arrest this process The histological changes need not detain us except to remark that if re-innervation does not occur the interstitial proliferation of connective tissue becomes predominant

until ultimately most of the muscle is replaced by fibrous tissue This change is permanent and unaffected by subsequent re-innervation More

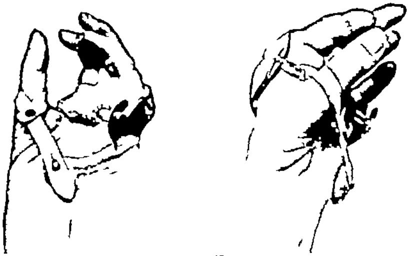

FIG 434

Combined median and ulnar splint In this case the patient had complete median and ulnar palsy with severe clawing controlled only by this splint. Although paralysis of the hand is still almost complete he has returned to his occupation as a hairdresser

interesting changes are *fibrillation* and increased oxygen consumption This unceasing fine inco-ordinate twitching of degenerate muscle may continue for years and may well be the reason not only for the increased

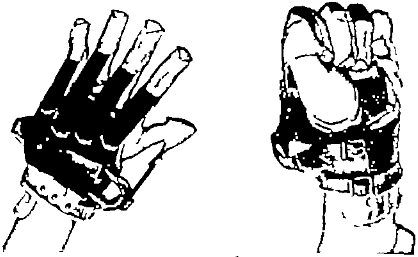

FIG 435

Splint for musculospiral paralysis. The only significant addition is a little trough on the ulnar border of the hand, which prevents deviation to the ulnar side

metabolism but also for the atrophy which must then be regarded as an expression of exhaustion the muscle wearing itself out This is the view put forward by Langley and by Tower and if correct its bearing on treatment

is obvious. Degenerate muscle can be made to contract by galvanic stimuli, and it has long been the custom to recommend galvanic stimulation during the period of denervation to keep up some sort of activity in the muscle until new motor fibres reach it. But it has been shown that this regular stimulation does not prevent atrophy and, if Langley is right, can only aggravate it. It is possible that Langley's experiments were not continued for a sufficient length of time, that whereas the early atrophy is inevitable, late atrophy may yet be prevented. This possibility is now being examined—though in the meantime the clinician is left with little to guide him. During the last war daily galvanic stimulation of paralysed muscles was practised almost universally, and many good recoveries were reported. Whether they would have been better or worse in the absence of such treatment cannot be told. Until more evidence one way or the other is forthcoming the clinician must remain in the dark, though it will comfort him to know that recovery can and does occur whether galvanism is employed or not.

Movements—Splinting can be overdone. The function of a splint is to prevent paralysed muscles from being stretched, not to fix joints. This war has already produced lamentable evidence of ignorance of this simple principle, and in some cases the final disability has been due more to joint stiffness than to the nerve lesion. The harmfulness of passive movements in the treatment or attempted prevention of joint stiffness resulting from injury or infection has been so clearly revealed that it has tended towards a general condemnation of passive movement of joints in general. But in a paralysed limb active movement is often impossible, and in many cases the joint is undamaged. Unless there is some clear contraindication, the joints of a paralysed limb should be put through a full range of movement once daily; if the movement is carried out with care the paralysed muscles will not be stretched to a harmful extent, and provided stretching of the sutured nerve has been carried out gradually until full length has been obtained, the nerve will not suffer damage. If some degree of stiffness is present when the patient is first seen, the range of movement should be gradually increased by passive movements. If this fails, gentle manipulation under anæsthesia is permissible, the surgeon contenting himself with obtaining a small increase at the first session, and not proceeding to further manipulation until this gain is assured.

Exercises—Attention has already been drawn to the axonal criss-crossing that occurs at the suture line, a confusion which manifests itself functionally as inco-ordination when recovery occurs. In some instances (particularly after suture of the ulnar nerve) this loss of co-ordination, an inability to perform fine dissociated movements, is permanent, but it may be minimized by intelligent re-education of the patient in the use of his hand. The stereotyped exercises of the massage department are of some value, but the best stimulus is provided by occupational therapy. There is a wide field of choice of occupational exercises, and it is possible to arrange them in series to cover every phase of recovery. An added merit is that they call for the exercise of tactile discrimination. The most depressing sequel of a median nerve injury, even when recovery is well advanced, is the loss of tactile discrimination in the index finger and thumb, the sense that is manifested clinically by the two-point test. There is now little doubt that recovery

of this sense must wait on the arrival of an adequate number of touch fibres in the affected zone but when they arrive it is certain that many of them reach destinations that are foreign to them and the patient must learn how to interpret correctly the sensations conveyed to him by endings arranged in a new and unfamiliar pattern This calls for long and patient effort which is best encouraged by suitable occupations in which tactile discrimination should play an increasingly important part

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CHAPTER LIII

WOUNDS OF TENDONS

THE BUNNELL-MAYER TECHNIQUE OF TENDON SUTURE

WHILE the end results of repair of severed tendons particularly those contained in special sheaths, still leaves much to be desired, substantial improvement has been noted by many surgeons who have adopted the Bunnell-Mayer method of suture in suitable cases It should be noted that silk is used for this suture, and that unabsorbable material be employed is an integral part of the Bunnell-Mayer technique In this connection the findings in O'Shea's interesting study of no less than 870 cases of severed tendons is contrary to what we might expect

Suture Material	Suppuration followed in
Catgut	15 per cent
Silk	3 ,,

Bunnell, in a recent communication, states that his results have been still further improved by the use of fine stainless steel wire No 34 in place of silk

The Bunnell-Mayer suture is more difficult to describe than to execute, but we hope, with the aid of the diagrams (Fig 436), the reader will have no difficulty in understanding it

A fine straight round needle is attached to each end of a piece of silk 10 in long , the size of the silk varies, depending on the size of the tendon , braided No 2 silk is usually right for the flexor profundus tendon The stitch is inserted as follows the operator, grasping mosquito forceps fixed to the edge of the stump of the tendon, steadies the tendon against the index finger of the left hand, and with one needle transfixes the tendon horizontally ½ in from the severed end (Fig 436 (1)) One needle traverses the tendon obliquely at an angle of 45°, emerging on one side (Fig 436 (2)) The procedure is repeated, using the other needle (Fig 436 (3)) The forceps is then removed and the tendon steadied by holding on to the two silk threads, and the traumatized tip of the tendon is removed with a very sharp knife (Fig 436 (4)) so that a clean cross-cut of tendon is visible One additional stitch is then taken with each needle, bringing the silk stitches out as near the centre of the tendon as is possible (Fig 436 (5)) Traction of 2 to 3 lbs is put on the silk so as to take in all the slack and bury the silk in the substance of the tendon An exactly similar stitch is taken in the other cut tendon end Each strand of silk is tied separately to the corresponding strand protruding from the opposite tendon end (Fig 436 (6)) In tying these knots accuracy is essential Sufficient tension must be

applied to cause the tendon ends to buckle a trifle When the suture has been completed the two tendon ends ought to be in perfect apposition (Fig 436 (7)) the silk knots buried between the tendons so as to be invisible No silk should show on the surface of the tendon at any point There should be no raw surface of the tendon exposed at the suture line

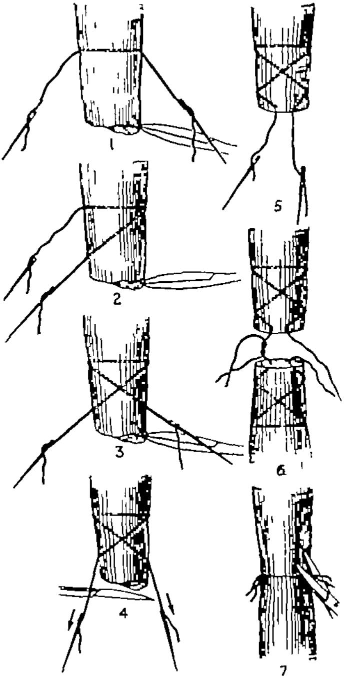

Fig 436

The steps of the Bunnell-Mayer suture If further strength is required, another " X " may be stitched into the tendon.

The Bunnell Mayer suture is quite unsuitable for flattened tendons and when there is no tension the button hole operation is eminently satisfactory A vertical slit is made in the upper part of the distal segment of the tendon (Fig 437) Through this

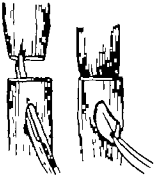

Fig 437 Fig 438

The " button hole " method of joining a flattened tendon.

is drawn the proximal end (Fig. 438) which is then sutured securely to the edges of the button hole

When for any reason, notably tension the above procedure is impracticable Harmer's suture may be found of value The illustration presents the method Four sutures are used—two in the proximal and two in the distal ends of the tendon Each stitch is commenced about 1 in from the severed ends It will be noted that the last step entails tying the ends which have been held in the hæmostats alongside the tendon These serve as lateral splints

(Fig. 439) They must not be tied too tightly, in order to avoid buckling. This suture was designed for use with catgut.

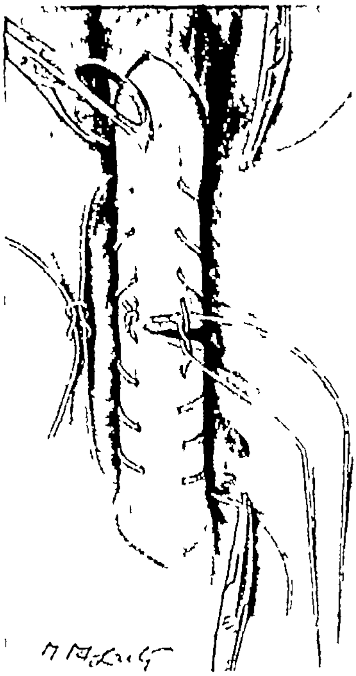

Fig. 439
Harmer's method of tendon suture

OTHER POINTS CONCERNING TECHNIQUE OF TENDON SUTURE

Retrieving retracted tendons—When a tendon has been severed through a comparatively small wound, usually the proximal end retracts about 2 in. and the distal end about 1 in. The original wound should not be enlarged in the line of the tendon, for this practice tends to disseminate infection and also, even in aseptic cases, to increase the liability to adhesions and scar formation. The lower severed end can usually be found in the original wound. If there is difficulty in locating the upper end, a small transverse incision is made at the point where the surgeon expects to find the retracted stump.

Preserving the endothelial covering—Again, with the object of preventing adhesions, the tendon stumps must be handled very carefully, always with the view that their delicate covering should be traumatized as little as possible. The Bunnell-Mayer technique of steadying the tendon with a fine hæmostat localizes surface trauma to a minimum. When it is not practicable to grasp the tendon in this way, a Lane's forceps employed as shown in Fig. 439 is comparatively atraumatic and gives splendid purchase.

Preventing tension—Blumm gives what may well prove to be an important principle in tendon suture. In order to relieve tension, say, in the case of a flexor tendon in the forearm, he partially divides the muscle belly. In this way there is little or no pull on the suture line and the necessity of keeping the wrist flexed is obviated. Muscle, he says, heals very readily, and by the time the tendon has united the muscle has regenerated. The procedure is recommended particularly for secondary suture.

WHY IS THE PROGNOSIS BETTER IN THE CASE OF EXTENSOR TENDONS?

All published results agree in one particular: the prognosis from a functional point of view is distinctly better in the case of extensor as opposed to flexor tendons. While no satisfying explanation is given in the literature, it is not difficult to extricate one. A large proportion of cut flexor tendons are concerned with the fingers. When a flexor tendon within its digital sheath has been cut, the conclusion reached by one of us (T. B. M.), who has had twenty-five years' experience in a city in which the local trades predispose to such injuries, coincides exactly with that of Teece, who writes: "In an experience covering some hundreds of cases of tendon injuries, I have never seen a case of successful primary or secondary suture when the point of division has been actually within the flexor sheath itself."

Coates remarks that a surgeon who can produce case records in which suture of a flexor tendon in its digital sheath has led to useful voluntary movement will incite considerable interest in his method

Bove has obtained this long looked for result in four consecutive cases in what is agreed generally to be the most regularly disappointing site for tendon suture viz the flexor tendon of a finger Bove s intriguing method is as follows The tendon ends are found grasped atraumatically and drawn well into the wound The tendons are then transfixed with pins well away from the site of severance (Fig 440 A) The cut ends are united with two simple silk sutures and the wound closed The finger and the finger only is encased in plaster which incorporates the pins the finger being in the flexed position (Fig 440 B)

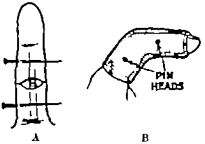

Fig 440

Bove s method of suture of a digital flexor tendon. A, Showing pins immobilizing the tendon. B, A plaster cast incorporating the pins with the finger in semiflexion

POSSIBLE METHODS OF PREVENTING ADHESIONS

Cargile membrane fat fascia lata cellophane etc have all proved unsatisfactory Amnioplastin a membrane prepared from human amnion promises well it is certainly more effective than any wrapping material yet devised Amnioplastin sets up no phagocytosis or cellular reaction and it becomes absorbed completely within a period of thirty days The membrane is preserved in 70 per cent alcohol and boiled for half an hour in distilled water just before use It is not unduly fragile is easily handled and resembles rather thin oiled silk

PRIMARY OR SECONDARY SUTURE ?

If the advice set out in this chapter is followed there will seldom be difficulty in deciding whether tendons should be sutured forthwith or no It should be noted that in all probability if secondary suture were employed in a case suitable for primary suture the final result would be equally good Emphatically the converse is not true Bearing this in mind Heck s investigation of seventy five cases reveals secondary suture in a particularly favourable light

	Good result
Primary suture—	
Extensor tendons	04 6 per cent
Flexor tendons	43 4
Secondary suture—	
Extensor tendons	62 5
Flexor tendons	25·0

If there is real doubt concerning contamination of the wound it is better to perform secondary suture This advice still holds good after taking into consideration the possible benefits which accrue from sulphanilamide

therapy The main argument against primary suture is *that its failure* not only still further jeopardizes the severed tendons, but, should infection supervene, it will probably impair the function of uninjured neighbouring tendons

Böhler's teaching is this—*Refrain from performing tendon suture in a contaminated wound complete the immediate operation by suture of the skin alone*

It is especially important to secure complete approximation of the skin over tendons, even in cases where the tendons are uninjured In order to leave potential free drainage within the wound as far as the sutured skin, fascial planes should not be sutured If Böhler's good advice is followed, cut tendon ends can be sutured under conditions of strict asepsis at a second operation This regime has an additional and not unimportant advantage—it saves time in rush periods following the admission of a batch of casualties In wounds with loss of skin, efforts should be made to obtain a skin covering, at least over that portion of the wound involving tendons

The insertion of suture material into the cut tendon ends, to be ready for tying at a second operation, has been suggested This practice seems inadvisable, for it is a fundamental principle that placing extraneous matter into a contaminated wound must be avoided rigorously

APPLICATION OF THE PRINCIPLES ENUNCIATED

Recent clean-cut wounds—Manifestly primary suture is indicated Wounds by broken glass, so common in peace and in modern war, are eminently suited to this procedure

Recent wounds which are not clean-cut—Under this category are included wounds inflicted by agents which common sense dictates are certainly infected War wounds, with the exception of some bullet wounds, must all be regarded as heavily contaminated If the injury is less than twenty-four hours old, and there are no visible signs of infection, the usual wound excision is carried out When a tendon is not severed completely, sometimes its continuity can be preserved by cutting away the ragged contaminated portion only If the tendon is severed, its ends are resected with a scalpel so as to leave a clean surface No attempt is made at tendon suture Primary closure of the skin must be very exact and throughout its depth The skin is thin and mobile over many sites of possible tendon injury, *e g*, the flexor surface of the forearm, and relatively deep interrupted sutures, combined with mattress sutures superficially, have proved a reliable method of obtaining accurate approximation

Immediate post-operative treatment—In the case of wounded tendons where wound excision without tendon suture is necessary (*i e*, an early *but grossly contaminated* wound), immobilization is carried out with the same exactness as if a fractured bone was involved However, if the wound remains aseptic, the period of this immobilization need not be longer than a week or ten days Another excellent principle is to elevate the part in order to reduce œdema, so for the upper limb of an ambulant patient any good abduction splint can be employed, for the lower limb the Böhler-Braun splint is excellent

Evacuation—If the primary operation has been performed at a casualty clearing station Sir Anthony Bowlby's advice regarding the inadvisability of immediate evacuation after primary suture should be remembered If a wound involving tendons has been treated by primary closure of the skin the patient should be retained under observation for at least four or five days If at the end of this time there are no signs or symptoms of infection he may be evacuated but the importance of a note however short stating what was found and done at the primary operation must never be forgotten

When to perform secondary suture—After primary closure of the skin if no suppuration has occurred the scar presents a healthy appearance and there are no areas of tenderness secondary suture can be undertaken on the twelfth or fourteenth day there is no advantage in waiting any longer When a low grade infection lasting say for a week or ten days supervenes Koch advises waiting three months After frank suppuration an interval of six months must intervene indeed in the case of a severe streptococcal infection it is probably advisable to wait twelve months

METHODS TO BE ADOPTED IN SECONDARY SUTURE OF TENDONS

The wound has healed by first intention—Under these circumstances comparatively little difficulty is experienced in retrieving the cut ends of the tendons Once the skin has been reopened along the line of the scar from the point of view of the operation the problems met with differ little from those presented in the primary operation Of course usually there will be more tension to be overcome when approximating cut ends For this reason the Bunnell Mayer suture can be employed infrequently When the loss of substance is considerable tendon grafting or tendon transplantation will be necessary (see p 385)

The wound has healed by second intention—It is inevitable that after a wound involving a tendon has suppurated for weeks or months the severed ends will have retracted and in all probability they will have become buried in scar tissue The muscles concerned can be made to contract but they exert no pull on their corresponding tendons Before undertaking treatment of such a case certain principles must be assimilated

1 It is essential that sutured tendons should be covered by normal whole skin and not scar tissue The cutaneous scar must therefore be excised completely In order to effect approximation of the skin it may be necessary to make counter incisions 2 or 3 in from the wound edge subsequently the resulting bare patches which are well away from the original wound can be covered with a skin graft

2 There should be no associated nerve lesion Tendons share in the general dystrophy of denervated tissues

3 The associated joint must be movable In the case of a digit it is obviously a waste of time to attempt to repair the tendons of a stiff finger If the finger or fingers are contracted they must be straightened gradually by using splints and appliances In this connection the Volkmann contracture or finger extension splint (Fig 442) is of service

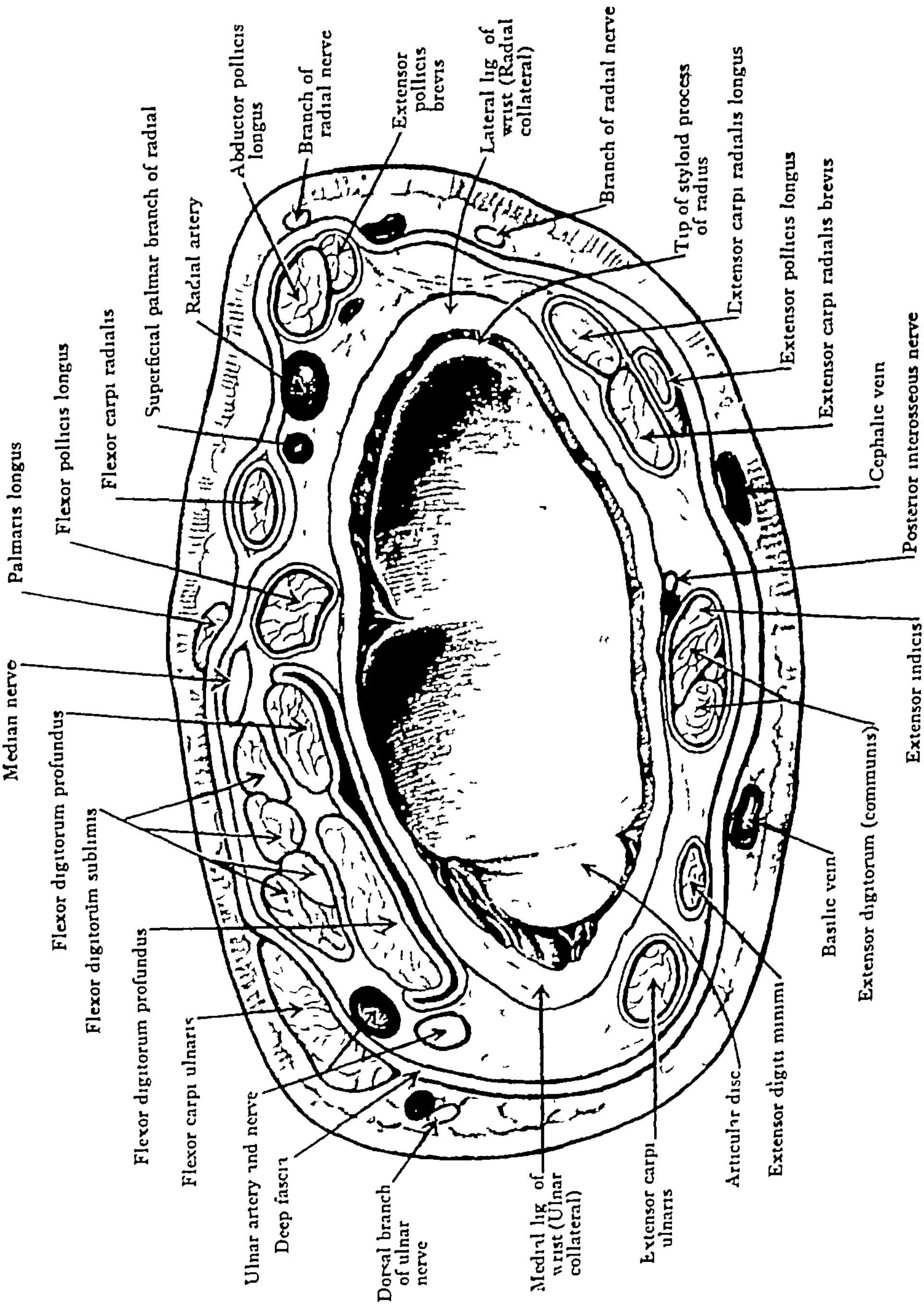

FIG 441
Relations of wrist joint (*Jameson*)

4 The surgeon must be familiar with the anatomy of nerves and tendons of the region The most frequently injured tendons are those of the fore arm The relationship of the flexor tendons to the nerves just above the level of the anterior annular ligament (flexor retinaculum) is shown in Fig 441 which may prove helpful

5 In many situations local anæsthesia is advisable When the tendons have been dissected out of the scar tissue the patient is instructed to move

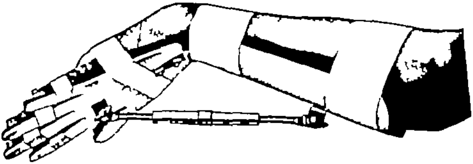

Fig 442

Volkmann's contracture splint (*Lesden Splint Co.*)

the part concerned If contraction of the muscle produces pull on the corresponding tendon we know that the proximal end is sufficiently free to justify anastomosis

METHODS OF BRIDGING A GAP

In some situations (viz in the forearm near the muscle bellies) and under certain conditions it is possible to dissect the tendons in such a way as to leave fibrous tissue partially forming a connecting bridge If this principle is adopted it is often sur prising to find that not only is there no tension between the two ends but actually the re made tendon requires shortening In similar situations when scar tissue cannot be utilized in this manner a piece of fascia lata can be used to bridge the gap The skin of the thigh should have been prepared beforehand with this possi bility in view

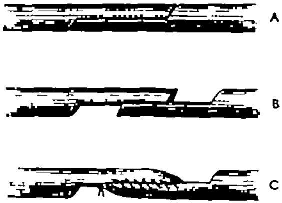

Fig 443

One of several methods which can be em ployed for lengthening a tendon

A, Line of incision. B, Position of tendon ends after lengthening C, Tendon ends sutured in lengthened position.

In still other contingencies particu larly when the tendon is a large one and in good condition, tendon length ening can be employed (Fig 443) Yet again in appropriate cases surgical ingenuity may dictate that one of

the ingenious exploits of tendon transplantation, of which Figs 444 and 445 are examples, meets the needs of the case.

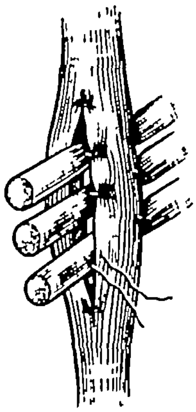

Fig 444
Three tendons passed through another tendon which has been split to receive them
(*After Sir Robert Jones*)

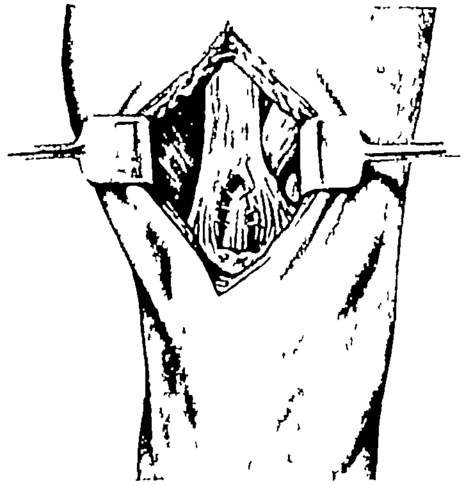

Fig 445
Transplantation of the tendon of the biceps femoris The tendon has been brought through an opening in the quadriceps and anchored there (*After Horsley*)

Such measures as the above are useless in the case of tendons normally contained in well-defined sheaths Bunnell writes "When a tendon in a finger or hand is found to be rough, cicatricial and grossly adherent, it is better to remove it and replace it with a new one" Bunnell has had an experience of 259 free autoplastic tendon grafts (Fig 446) over a period of fourteen years In the case of forearm and hand the palmaris longus is a fruitful source of supply, a tendon from the flexor sublimis or one of

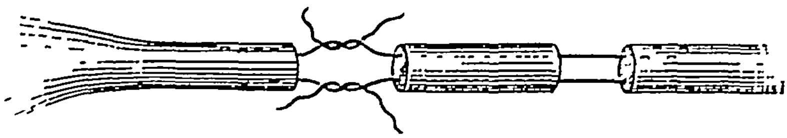

Fig 446
Lengthening a tendon by means of an autogenous graft (*After Bunnell*)

the long extensors of toes can also be utilized Tendons are grafted with what Bunnell calls their "paratenon," that is, the specialized elastic fat which immediately surrounds them.

If the flexor tendons are severed in a finger in the usual place, opposite the proximal phalanx, they cannot be sutured with success, as the junction will become adherent in the narrow sheath It is better to remove the tendons entirely from the finger and graft a new tendon The suturing is then done in the palm, where adhesions will be of less importance, and to the distal phalanx One flexor tendon in a finger must suffice

The graft is sutured to the profundus in the palm, and a silk suture is fixed to its other end The base of the terminal phalanx of the finger is cut down on by two short lateral incisions and the eye end of a probe is passed up the empty flexor tunnel into the palm, threaded with the silk and withdrawn to pull the tendon graft down the tunnel covered by the intact

or reconstituted soft parts The front of the base of the distal phalanx is scraped for bony contact and the end of the graft is fixed by a suture passed through a tiny drill hole made through the bone (Bunnell) (Fig 447)

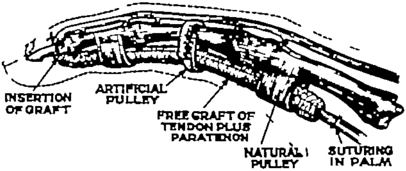

Fig 447

Method of replacing a flexor tendon of a finger by an autogenous graft. It will be noted that an artificial pulley has been constructed from a free piece of tendon (*After Bunnell*)

TENDON SUTURE POST-OPERATIVE TREATMENT

All are agreed that movement should be begun as soon as possible following the operation While this ideal should be our aim reasonable discretion must be exercised. If the surgeon envisages that his suture is strong and tension is not excessive obviously immediate movement is indicated Extensor tendons require more guarding than flexor tendons By suitable splinting tension on sutured tendons can be released gradually

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SECTION XII

METHODS OF IMMOBILIZING THE LIMBS

CHAPTER LIV

THE APPLICATION OF PLASTER OF PARIS

SPLINTS of metal and wood require attention and adjustment even so immobilization is sometimes imperfect A plaster cast correctly applied provides immobilization second to none for it grips the entire circumference of the limb and it calls for the minimum of attention

Plaster of Paris is a fine white powder made from the stone gypsum, which is pulverized and heated so that the water of crystallization is driven off. The resulting anhydride calcium sulphate can combine with water and the re-crystallization which then takes place is known as "setting.

As a splint plaster is used in two forms (1) as bandages made of book muslin impregnated with starch rolled in dry plaster powder and (2) as sheets of muslin which are impregnated with wet plaster paste The latter are chiefly used for making plaster beds but can also be employed in making shoulder spicas or hip spicas Sheet muslin calls for expert plaster technique and it is also a more expensive method

Plaster bandages are made as follows The muslin the meshes of which should be about twenty four threads to the inch is torn into widths of 3 4 5 6 and 8 in. Half a dozen longitudinal threads should be removed from each side of the width Dry plaster-of Paris powder is placed on the flat muslin and smoothly spread out by hand (Fig 448) or by means of a wooden board and the bandage thus becomes evenly filled with plaster as it is rolled The 3 and 4 in bandages should be 9 ft long and the 5 6 and 8 in bandages should be approximately 12 ft long Bandages 8 in wide should weigh 9 oz bandages 6 in wide should weigh 7 oz and bandages 4 in wide should weigh 6 oz If every bandage is weighed after it is made the sister making them soon learns the right amount of plaster to incorporate in each The bandages should not be rolled too tightly as this will prevent the water reaching the centre sufficiently quickly Dry plaster strips of varying

FIG 448

Plaster bandages being made The left hand is rolling the bandage while the right hand smooths out the plaster powder

thickness can also be made Bandages and strips should be stored in large zinc boxes It will be found convenient to keep those required for current needs in biscuit tins painted black, with the size of the bandage marked on each tin

As a rule the home-made bandages are preferable to proprietary ones They are less expensive and they bind better when applied to the trunk However, the proprietary brands have advantages individual bandages contain more plaster, consequently a lighter cast can be made over the extremities Dry plaster strips can also be made and stored in the same way as plaster bandages To have the strips ready-made saves time

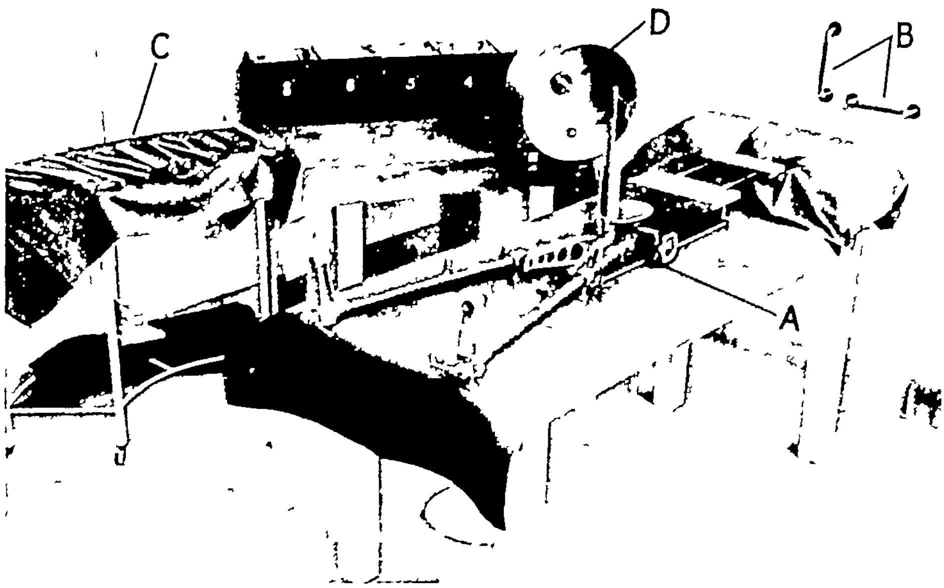


Fig 449

A, Portable orthopædic or fracture table B, Brackets for exerting traction C, Various plaster-removing instruments D, Metal drum for making plaster strips

Plaster work, where possible, should be carried out in a specially equipped plaster theatre Essentials are as follows —

Plaster of Paris bandages
Stockinet in various widths
Felt—grey felt is the cheapest, and if placed over stockinet can be tolerated by the patient It is about 1 in thick, but can easily be stripped into smaller thicknesses
Ordinary white cotton-wool, rolled in bandages 6 in wide, 6 ft long and one-half of the thickness in which it is usually sold
Brown wool, wood wool or dressmakers' wool, which should be doubly sterilized if it is to be in the proximity of abrasions or wounds, as it may contain tetanus spores
Cotton bandages
Strapping (adhesive plaster)
Webbing straps
Flexible aluminium strips

A table for making plaster strips This should be glass topped for easy cleaning
An orthopædic or fracture table (Fig 449 A)
At least two buckets in stands
Brackets attached to the wall (Fig 449 B) and hooks to the ceiling for traction and suspension
Plaster removing instruments of various types (Fig 449 C)
Strong scissors and scalpels
Böhler s walking irons and spanners for bending them
Indelible pencil

Useful adjuncts are a metal drum (Fig 449 D) for making plaster strips and a sink at ground level for soaking plaster casts prior to removal The plaster room should be sufficiently large to contain two operating tables including an orthopædic table which can maintain the lower limbs in wide abduction and a mobile X ray apparatus

METHOD OF APPLICATION

Plaster casts are applied as follows —

(a) Unpadded or over stockinet as in casts for the extremities
(b) Over stockinet with felt padding over the bony prominences as in spinal jackets
(c) Over a light layer of wool preferably maintained in position by a cotton bandage This method should be employed in shoulder plasters hip spicas and always after operation on limbs where a tourniquet has been used and after operation on compound injuries

General instructions—Care must be taken to see that drops of water do not fall into the tin of plaster bandages during the operation A bandage is put into a bucket of warm water to which salt a drachm to a pint has been added The bandage should soak until air bubbles cease to rise During the application one bandage must always be in the water ready for use Using both hands the soaked bandage is grasped at each end between the finger and thumb the finger and thumb being pressed together so that no plaster can escape The two ends are approximated and pulled apart again The concertina like movement expresses the required amount of water and the first 6 in only of the bandage is unrolled and handed to the surgeon who grasps the bandage in his right hand and the unrolled part in his left The bandage is applied evenly without any tension and the hand is passed over each layer smoothing it out before the next is applied The plaster should be moulded firmly over all prominences such as the malleoli the knees and the anterior superior spines of the ilium The assistant supporting the limb should do so with the flat of his hand and not with his fingers otherwise the indentation so produced may lead to a plaster sore

Plaster strips—These are made in different lengths as required the necessary length being determined by measuring with a strip of cotton bandage first They can be made by rolling a bandage backwards and forwards on the plaster table smoothing each layer over before the next is

thickness can also be made. Bandages and strips should be stored in large zinc boxes. It will be found convenient to keep those required for current needs in biscuit tins painted black, with the size of the bandage marked on each tin.

As a rule the home-made bandages are preferable to proprietary ones. They are less expensive and they bind better when applied to the trunk. However, the proprietary brands have advantages: individual bandages contain more plaster, consequently a lighter cast can be made over the extremities. Dry plaster strips can also be made and stored in the same way as plaster bandages. To have the strips ready-made saves time.

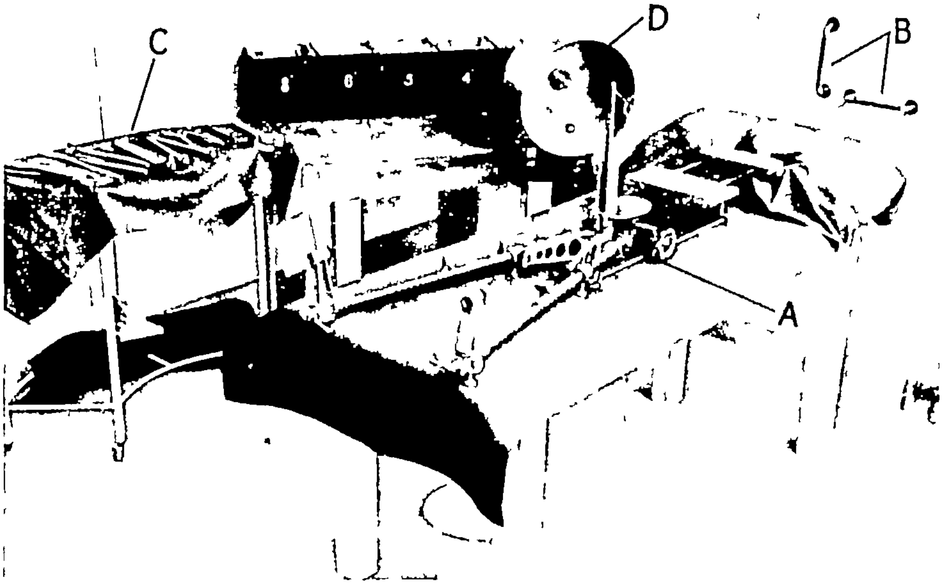


FIG. 449.
A, Portable orthopædic or fracture table. B, Brackets for exerting traction. C, Various plaster removing instruments. D, Metal drum for making plaster strips.

Plaster work, where possible, should be carried out in a specially equipped plaster theatre. Essentials are as follows:—

- Plaster of Paris bandages.
- Stockinet in various widths.
- Felt—grey felt is the cheapest, and if placed over stockinet can be tolerated by the patient. It is about 1 in. thick, but can easily be stripped into smaller thicknesses.
- Ordinary white cotton-wool, rolled in bandages 6 in. wide, 6 ft. long and one-half of the thickness in which it is usually sold.
- Brown wool, wood wool or dressmakers' wool, which should be doubly sterilized if it is to be in the proximity of abrasions or wounds, as it may contain tetanus spores.
- Cotton bandages.
- Strapping (adhesive plaster).
- Webbing straps.
- Flexible aluminium strips.

(d) *Tourniquets*—Plaster is sometimes applied after an operation has been performed with a tourniquet on the limb Here unpadded plasters must not be used A woollen bandage firmly bound on with a cotton bandage is the method of choice as this seems to make a cushion of sufficient hæmostatic pressure without causing undue obstruction

When interference with the circulation is suspected the limb should be elevated to an angle approaching the perpendicular to prevent venous stasis which might cause further obstruction

PREVENTION OF CIRCULATORY OBSTRUCTION—Toes and fingers must be inspected carefully during the first twenty four hours Swelling may take place after a fracture but if the fracture has been reduced this should not cause serious circulatory interference Provided the toes remain pink and warm there is no cause for alarm The spectrum of circulatory disturbance and gangrene is as follows —

Pink red purple blue black The black of established gangrene is of academic interest only Pink and red are normal Purple or blue indicates serious interference and the plaster must be bi valved or cut through In plasters applied after open operations it is important to cut the plaster and dressing down to the skin A dressing soaked and hardened with blood within a plaster cast is a fruitful source of impairment of the blood supply to that limb If circulatory obstruction is anticipated it is an excellent practice to cut a gutter 1 in wide through the plaster right down to the skin (Fig 450) before the plaster has set This provides an ample safety valve for swelling and does not disturb the position of the bones Cutting down the plaster and opening it out relieves circulatory obstruction but it often fails in maintaining the position of the fracture

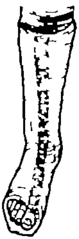


FIG 450

A "guttered plaster The portion shown is removed right down to the skin.

Plaster sores occurring in the skin in the proximity of the edges of the cast are due to swelling beyond, or failure to round off the edge of the plaster The edges of a plaster should always be turned back with the underlying stockinet and eased *beneath with the fingers If edges of the cast have to be* trimmed, they should be cut straight through or even sloped towards the inner aspect of the plaster they should never be cut so that a sharp edge is left Should a sore occur in the situation under discussion pressure must be relieved by a longitudinal cut in the plaster which can then be lifted from the region of the sore

Plaster sores are also caused by irregularities in the plaster and by undue pressure at certain points Irregularities in the plaster are due to errors in technique undue pressure to faulty nursing

Plaster sores should be suspected when the patient complains consistently of pain at one site for two or three days If an odour of sepsis is present the plaster should be removed locally so as to display the painful area If a sore is present it should be cleaned with spirit dressed with flavine and paraffin, and fresh plaster laid on over it It should be remembered that when treated a sore is bound to heal the maintenance of position for which the plaster was applied is of much greater importance Therefore as a rule the removal of a plaster on account of a sore is to be condemned

applied The strips may be trimmed with scissors or a knife before application to accommodate them to the various regions

Strips are rapidly produced by means of a metal drum The bandage is laid on the drum, and the drum turned with one hand by the handle in the centre The strip is constantly smoothed over by hand, and when it is of the required thickness it is cut through the slit in the drum

When applying the strip it should be cut through to a third of its width in the region of a flexed joint, such as the angle of the elbow and over the heel, as otherwise the plaster will wrinkle and is likely to cause sores

The use of strips is to be preferred in all plasters, but when applying casts to the limbs they are essential It cannot be stressed too strongly that a circular bandage applied to a limb without a preliminary strip or strips is dangerous

Plaster of Paris sets in approximately ten minutes All the time the plaster is being applied it should be rubbed and smoothed, this makes for stability and lightness The thickness of a plaster is no criterion of its strength, as if it is not rubbed in there will be air between the layers, making for weakness A smooth interior is more important than a smooth exterior, but the latter is pleasing both to the patient and the surgeon

CLOSED PLASTER TECHNIQUE OF WOUNDS

After thorough wound excision in the case of a recent wound, or débridement in the case of a visibly infected wound, the wound is packed In the former case dry gauze, vaseline gauze or gauze impregnated with cod-liver oil, each have their advocates Dry gauze should never be used in infected wounds

Whenever the closed plaster is employed for wounds vaseline should be rubbed into the skin of the entire limb on which the plaster is to be applied, otherwise the discharge from the wound seeping under the plaster may cause dermatitis

COMPLICATIONS

Interference with the circulation—CAUSES—(*a*) *Plaster applied too tightly*—This should never occur Actually, plaster of Paris expands very slightly when it sets, but this is no excuse for putting tension on bandages during their application

(*b*) *Unpadded plasters over unreduced fractures*—This is a serious error An unreduced fracture is an impediment to the circulation, and additional obstruction in the shape of plaster encasement may prove overwhelming It is absolutely essential, therefore, when applying a complete unpadded plaster, to make sure that the fracture is reduced

(*c*) *Reduction of the angle of a joint after the plaster has been applied but before it has set*—This is a common fault, and occurs chiefly at the elbow and ankle The assistant holding the limb may have allowed it to sag to an angle greater than the usual 90°, and this is then corrected after the plaster has been applied It will cause the plaster to ruckle and indent on the anterior surface of the joint, and will result in (at least) a sore The plaster must be allowed to set with the limb in the position in which it was applied, the only alternative is a fresh plaster

THE DORSAL STRIP FOR A COLLES' FRACTURE

Twenty layers of Cellona bandage (Fig 451) or the equivalent in home-made bandages are used The strip should stretch from the head of the metacarpals to just short of the elbow joint The corners should be cut with the strip either wet or dry Removal of corner A allows free movement of the first metacarpal and removal of corner B prevents the plaster from pressing against the biceps tendon when the elbow is flexed The V shaped piece of plaster cut out on the opposite side is to permit ulnar adduction of the wrist When the wrist is fully adducted the points C and C_1 should be in contact

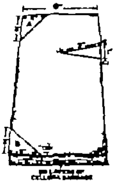


Fig 451

Colles fracture. Method of cutting the strips.

Application—Stockinet is applied to the arm and rolled up to the elbow as a preliminary to reduction. After reduction the forearm is held by an assistant and the stockinet pulled down into position It should overlap the length of the strip by 1 in at each end The wet strip is then placed in position care being taken to see that it reaches midway over the palmar surface of the wrist and covers the entire dorsal surface It is then bandaged into position with a 2 in cotton bandage starting from below up When set the stockinet should be cuffed back over the plaster and the edges smoothly rounded A strip of 2 in strapping secures the stockinet at the proximal end and also holds the cast in position. A similar piece of strapping secures the cast over the wrist-joint Two strips of strapping half an inch in width anchor the palm to the plaster crossing over the strapping behind These are in turn anchored by a further 2 in piece of strapping at the wrist (Figs 452 and 453)

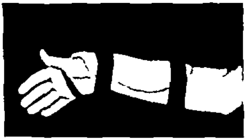


Fig. 452

Colles fracture. The plaster extends well over the front of the anterior surface of the lower end of the radius, but allows an ample gutter in case of swelling

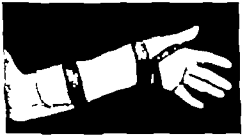


Fig 453

Colles fracture. Note that free movement of the first metacarpal is permitted, and that the plaster reaches the metacarpal heads but does not abut on the biceps tendon in flexion of the elbow

Precautions—

(a) The upper end of the plaster should not press against the biceps tendon in flexion of the elbow

(b) The plaster should be carefully moulded over the head of the ulna This is a common site for a plaster sore

(c) The edge of the plaster should be carefully rounded off at the base of the first metacarpal so that free movement of the thumb is allowed

THE DORSAL STRIP FOR A COLLES' FRACTURE

Twenty layers of Cellona bandage (Fig 431) or the equivalent in home-made bandages are used *The strip should stretch from the head of the metacarpals to just short of the elbow joint* The corners should be cut with the strip either wet or dry Removal of corner A allows free movement of the first metacarpal and removal of corner B prevents the plaster from pressing against the biceps tendon when the elbow is flexed The V-shaped piece of plaster cut out on the opposite side is to permit ulnar adduction of the wrist When the wrist is fully adducted the points C and C_1 should be in contact

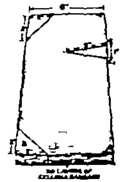


FIG 431

Colles fracture. *Method of cutting the strips.*

Application—Stockinet is applied to the arm and rolled up to the elbow as a preliminary to reduction. After reduction the forearm is held by an assistant and the stockinet pulled down into position It should overlap the length *of the strip by 1 in* at each end The wet strip is then placed in position care being taken to see that it reaches midway over the palmar surface of the wrist and covers the entire dorsal surface It is then bandaged into position with a 2 in cotton bandage starting from below up When set the stockinet should be cuffed back over the plaster and the edges smoothly rounded A strip of 2 in strapping secures the *stockinet at the proximal end and also* holds the cast in position. A similar *piece of strapping secures the cast* over the wrist-joint Two strips of strapping half an inch in width anchor *the palm to the plaster crossing over* the strapping behind These are in turn anchored by a further 2 in piece of strapping at the wrist (Figs 432 and 433)

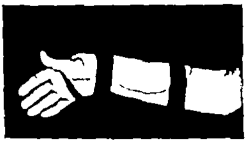


FIG 432

Colles fracture. The plaster extends well *over the front of the anterior surface of the* lower end of the radius, but allows an ample gutter in case of swelling.

FIG 433

Colles fracture. Note that free movement *of the first metacarpal is permitted*, and that the plaster reaches the metacarpal heads but does not abut on the biceps tendon in flexion of the elbow

Precautions—

(*a*) The upper *end of the plaster should not press against* the biceps tendon in flexion of the elbow

(*b*) The plaster should be carefully moulded over the head of the ulna This is a common site for a plaster sore

(*c*) The edge of the plaster should be carefully rounded off at the base of the first metacarpal so that free movement of the thumb is allowed

THE DORSAL STRIP FOR A COLLES' FRACTURE

Twenty layers of Cellona bandage (Fig 431) or the equivalent in home-made bandages are used. The strip should stretch from the head of the metacarpals to just short of the elbow joint The corners should be cut with the strip either wet or dry Removal of corner A allows free movement of the first metacarpal and removal of corner B prevents the plaster from pressing against the biceps tendon when the elbow is flexed The V-shaped piece of plaster cut out on the opposite side is to permit ulnar adduction of the wrist When the wrist is fully adducted the points C and C_1 should be in contact

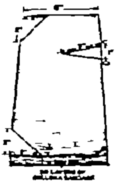


FIG 431

Colles fracture. Method of cutting the strip

Application—Stockinet is applied to the arm and rolled up to the elbow as a preliminary to reduction. After reduction the forearm is held by an assistant and the stockinet pulled down into position It should overlap the length of the strip by 1 in. at each end The wet strip is then placed in position care being taken to see that it reaches midway over the palmar surface of the wrist and covers the entire dorsal surface It is then bandaged into position with a 2 in cotton bandage starting from below up When set the stockinet should be cuffed back over the plaster and the edges smoothly rounded A strip of 2 in strapping secures the stockinet at the proximal end and also holds the cast in position A similar piece of strapping secures the cast over the wrist joint Two strips of strapping half an inch in width anchor the palm to the plaster crossing over the strapping behind. These are in turn anchored by a further 2 in piece of strapping at the wrist (Figs 452 and 453)

FIG 452

Colles fracture The plaster extends well over the front of the anterior surface of the lower end of the radius but allows an ample gutter in case of swelling.

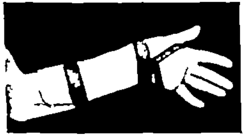


FIG. 453

Colles fracture Note that free movement of the first metacarpal is permitted, and that the plaster reaches the metacarpal heads but does not abut on the biceps tendon in flexion of the elbow

Precautions—

(a) The upper end of the plaster should not press against the biceps tendon in flexion of the elbow

(b) The plaster should be carefully moulded over the head of the ulna This is a common site for a plaster sore

(c) The edge of the plaster should be carefully rounded off at the base of the first metacarpal so that free movement of the thumb is allowed

(*d*) The strapping on the palm will have to be replaced in two or three days, as it will have become slack

(*e*) The plaster should not extend round the fifth metacarpal bone in front, as this will limit full flexion of the fingers

(*f*) An ample gutter should be left between the margins of the strip to allow for swelling

COMPLETE PLASTER OF THE WRIST FOR A FRACTURE OF THE SCAPHOID BONE

A strip similar to that for a Colles' fracture is used, and also a strip 3 in wide and slightly shorter on the palmar surface These are applied over stockinet with the wrist in slight dorsiflexion, and are bandaged into position by a 3-in plaster bandage Should the strips overlap, the redundant parts are cut away (Fig 454) This bandage grips the thumb as far as the metacarpo-phalangeal joint, and also passes between the thumb and the index finger round the head of the second metacarpal bone (see Fig 455) The 3-in bandage can be compressed with the fingers until the plaster bar which it forms is half an inch in width only As the plaster is setting it should be carefully moulded into the palm (Fig 455), and at the same time the patient should flex the metacarpo-phalangeal joints of the fingers to 90° so that the plaster does not extend further than the transverse crease of the palm The stockinet is cuffed back and secured by a plaster bandage (Fig 456)

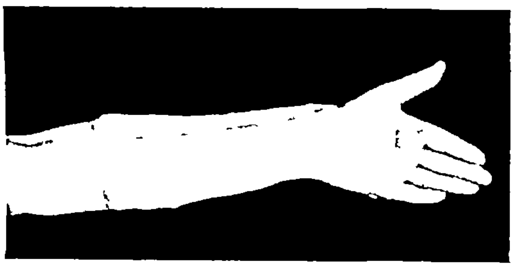


Fig 454

Scaphoid plaster Plaster strips in position

Fig 455

Method of moulding plaster well into the palm

Fig 456

Completed scaphoid plaster

Precautions—

(*a*) The first metacarpal bone should be completely immobilized

(*b*) The plaster should be moulded carefully into the palm

(*c*) The plaster will require rounding off in the region of the second metacarpal head

(*d*) Ninety degrees of flexion at the metacarpo-phalangeal joints must be possible

COMPLETE PLASTER OF THE FOREARM AND BÖHLER FINGER SPLINT FOR FRACTURED PHALANGES, ETC

A 3 in wide plaster strip is made similar to the anterior strip in the scaphoid plaster This is applied over stockinet as in the scaphoid plaster and is bandaged to the forearm with one 3 in plaster bandage The finger splint is applied unpadded while the plaster is still wet and bandaged to it by another plaster bandage The distal part of the splint is padded and the fractured finger is strapped to it The splint is then flexed to the requisite angle to maintain reduction of the fracture

Precautions—

(*a*) The upper end of the splint should not indent the plaster but should lie comfortably on it

(*b*) The plaster should not extend so far distally as to interfere with movements of the other fingers

POSTERIOR GUTTER PLASTER FOR FRACTURES IN THE REGION OF THE ELBOW-JOINT

A gutter plaster is to be preferred here because of the danger of ischæmia due to the great swelling which may take place in these fractures

Application—A strip of the required width 4 in in children and 6 in in adults, is made the precise length first being carefully ascertained It

Fig 437

Posterior strip being applied.

Fig 438

Posterior strip being bandaged on smoothly with cotton bandage

should extend from a point 3 in below the acromion to 2 in below the wrist joint (Fig 437) The inner and upper angle should be cut off and both lower angles should be folded over on themselves The distal end of the plaster folded over supports the hand without limiting the movements of the wrist After the fracture is reduced the plaster is applied over stockinet It is cut through to one-third of its width at the angle of the elbow and the overlapping portions are carefully moulded together It is then bandaged on with a 3 in cotton bandage starting from below (Fig 438)

After it has set it can be further anchored by a figure-of-eight cotton bandage passing from the forearm to the upper arm Either a sling or collar-and-cuff may be necessary as an additional support

Precautions—

(*a*) An ample gutter should be left on the anterior aspect

(*b*) Care should be taken that the plaster does not extend too high in the axilla

(*c*) The plaster should be sufficiently strong to support the weight of the forearm in flexion

THE COMPLETE ARM PLASTER FOR FRACTURES OF THE FOREARM AND ELBOW

It is necessary to maintain traction while this plaster is being applied. An assistant grasps the thumb and index finger in both hands, the patient being recumbent Counter-traction is obtained by means of a webbing strap

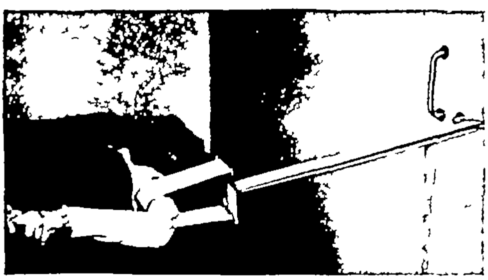


FIG 459

Traction and counter-traction for fracture of the forearm Traction is exerted on thumb and index finger only

FIG 460

Plaster strip being applied Note that it is cut through one-third of its width for accurate apposition at the elbow-joint

attached to a wall bracket (Fig 459) Stockinet should have been previously applied

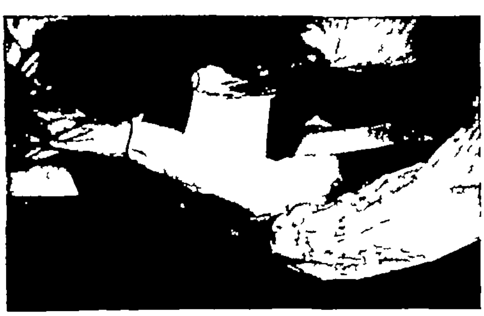


FIG 461

Strip being bandaged on by 4-in bandage

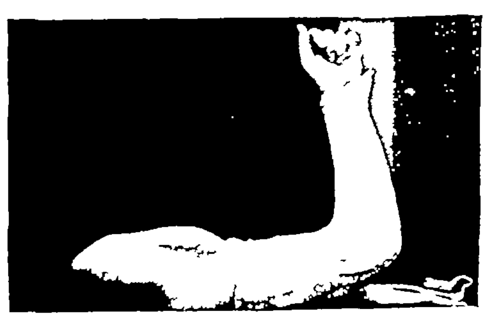


FIG 462

Palmar view Note indentation caused by pressure of thumb and finger This is a potential source of plaster sores.

Application—A strip is made exactly similar to that of the posterior gutter plaster above (Fig 460) A 4-in plaster bandage is now applied smoothly, starting from below up (Fig 461) It should be carefully moulded over the crease of the elbow A useful precaution is to place a piece of wool

2 in square in the crease of the elbow It will be found that the webbing interferes with the application of the bandage to the upper part of the arm but when the plaster is set immediately above the elbow the traction can be removed and the upper part of the plaster completed The stockinet is cuffed back and secured by a plaster bandage in the usual way (Fig 462)

Precautions—

(a) The fracture must be reduced A complete plaster applied over an unreduced fracture may cause serious obstruction to the circulation

(b) The plaster must not encroach on the axilla

(c) Care must be taken that the angle at the elbow is not decreased after application of the plaster but before it has set This will certainly cause a sore and may cause gangrene If the angle of the elbow is unsatisfactory a new plaster should be applied

THE SHOULDER SPICA FOR FRACTURES IN THE REGION OF THE SHOULDER

This vies with the hip plaster in being the most difficult to apply satisfactorily The optimum position is in 80 of abduction inclining forwards to 45 with the elbow at an angle of 90° In order to fix the shoulder at an angle of 80 it will be found necessary to apply the plaster with the shoulder at an angle of at least 90 of abduction, as the arm always comes down a little in plaster due to pressure on padding and soft parts With a conscious co-operating patient by far the easiest method is to apply the plaster with the patient sitting down holding a bracket on the wall (Fig 463) or with

Fig 463

Position for applying shoulder spica. Stockinet *in situ*; wool being bandaged on.

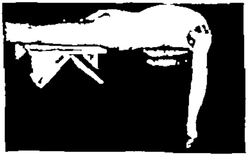


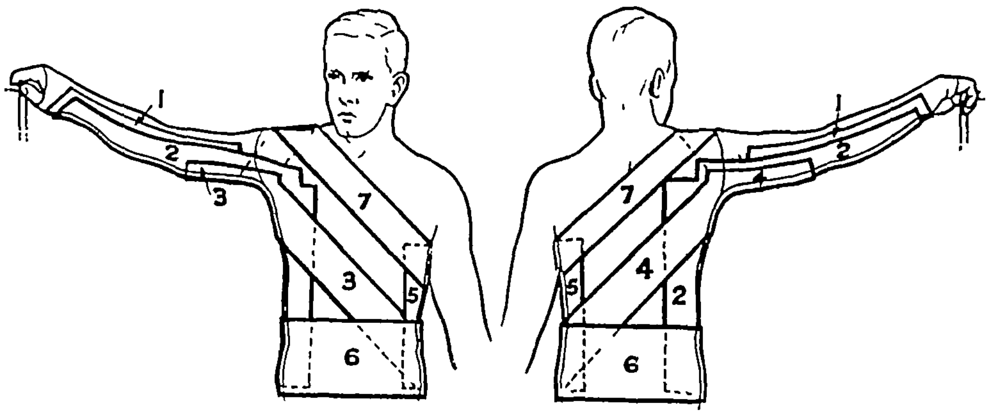
Fig 464

Alternative position for applying shoulder spica with patient prone

his arm held by an assistant With a patient under an anaesthetic or recumbent for any other reason an orthopaedic table may be used or if this is not available the patient's buttocks should be supported on a pelvic rest or wooden box and the opposite shoulder raised on sandbags The arm will then of course be held by an assistant A patient in a prone position with his arm allowed to hang over the edge of the table (Fig 464) is also in a suitable position for applying a spica This method can be

adopted in operations on the shoulder-joint where a posterior approach i used

Application—Stockinet of appropriate widths cover the trunk the arm and the opposite shoulder the pieces of stockinet are sewn together t form a vest A light woollen bandage is applied to the trunk an extra laye being placed over the anterior superior spines and also in the axilla and th crease of the elbow It is bandaged on smoothly with a 6-in cotton bandage



Figs 465 and 466

Shoulder spica Diagrammatic application of strips Strip 7 is in the shape of a figure of-eight, ending in the axilla

An alternative method is to use felt applied as in a spinal plaster jacket (see p 610) Seven plaster strips will be necessary, six strips 6 in wide and one 8-in strip (Figs 465 and 466) A strip is applied to the arm as in the posterior gutter plaster, and is bandaged on, as in a complete arm plaster, with a 4-in plaster bandage Before this has set the second strip is applied It extends from just above the elbow well into the axilla and

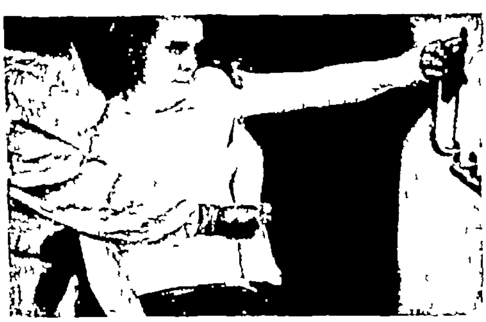


Fig 467

Second strip being applied to arm, axilla and side of trunk

Fig 468

Fourth strip, similar to third, but passing behind

along the side in the axillary line to 3 in below the crest of the ilium (Fig 467) It should be cut through one-third of its width in front and behind, so that it can be opposed accurately to the folds of the axilla It is then bandaged to the trunk The third strip extends from just above the elbow up into the axilla and obliquely across the front of the trunk to 3 in below the opposite anterior superior spine It is similarly bandaged to the trunk The fourth strip extends from just above the elbow up into the axilla then

across the back of the trunk to 3 in below the opposite crest of the ilium (Fig 468) The next strip is applied down the unaffected side It extends from 2 in below the axilla to 3 in below the crest of the ilium (Fig 469) These strips are bandaged to the trunk by several 6 or 8 in plaster bandages

Fig 469

Fifth strip applied down unaffected side

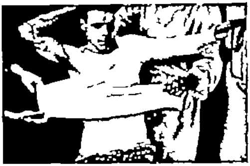


Fig 470

Last strip passing round chest This strip will overlap itself in the axilla.

The 8-in strip extends round the base of the trunk 3 in below the crest of the ilium If the patient is sitting down it should not encroach on his thighs in flexion The last 6-in strip extends round the chest at the level of the upper margin of the plaster (Fig 470) Its upper limit is 2 in below the opposite axilla and it may be made a little longer so that it overlaps itself in the axilla on the affected side During application the plaster should be constantly moulded over the bony prominences such as the anterior iliac spines and moulded well into the axilla The plaster can be trimmed into a V-shape (Fig 471) over the chest to allow for respiration or alternatively a round epigastric window can be cut The stockinet is cuffed over in the usual way If doubts are entertained as to the ability of the plaster to hold the arm in abduction, a strut of plaster can be made extending from the elbow to the region of the crest of the ilium but it is preferable to omit this if possible as in that case the patient will be unable to get his coat on over the plaster Additional aids to stability are aluminium strips and the extension of the plaster over the opposite shoulder

Fig 471

Completed shoulder spica, trimmed into a V-shape over chest to allow for respiration.

Precautions—

(a) Careful moulding of the plaster into the axilla is essential If air is allowed to remain between the strips an apparently thick plaster will inevitably give way

(b) The plaster should be carefully moulded over the internal epicondyle of the humerus This is a common site for a sore and the pressure may even cause ulnar paresis

(c) Care should be taken that the plaster is brought down low enough over the iliac crests It can be trimmed anteriorly to allow flexion of the thighs, but if it is not low enough it will chafe the skin over the spines of the ilium

LOWER-LIMB PLASTERS

These comprise —

1 The below-knee plaster for fractured metatarsals, tarsal bones, Pott's fractures and fractured tibiæ
2 The below-knee plaster incorporating pins or wire
3 The above-knee plaster for fractures in the region of the knee-joint or fractured tibiæ above the lower third
4 Single hip spica for fractures in the region of the hip-joint
5 Double hip spica

BELOW-KNEE PLASTER

The shortest plaster applied to the lower limb should be long enough to extend from the tibial tubercle to the tips of the toes Any plaster shorter than this will not give sound fixation Moreover, it will almost certainly chafe the skin of the leg at its upper limit

Application—The patient lies on his back, and the thigh is supported by sandbags with the knee bent Stockinet is applied to the limb It

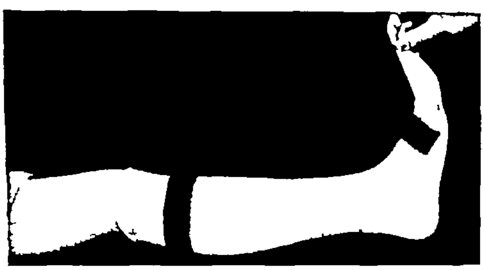


FIG 472

Below-knee plaster Stockinet and felt applied and maintained by strapping

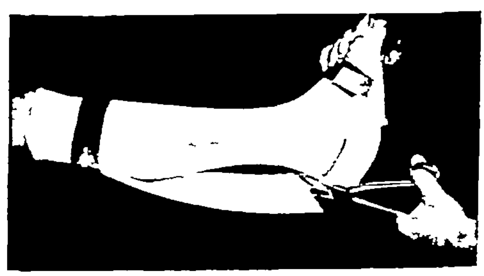


FIG 473

Posterior strip being applied

extends beyond the toes, and is grasped by an assistant who thus supports the limb (Fig 472) A posterior strip is made, its length being determined by measuring with a cotton bandage It reaches from just below the knee to the tip of the big toe It is applied over the stockinet, and is cut through one-third of its width on each side at the angle of the heel It is folded back over the little toe so that it extends for half an inch only beyond each toe (Fig 473) The plaster strip is then smoothly bandaged to the foot and leg by a 4 or 6 in plaster bandage The stockinet is cuffed back and secured by a plaster bandage when sufficient thickness has been reached

Precautions—

(a) The angle of dorsiflexion should not be changed while the plaster is setting This is one of the commonest causes of a sore or gangrene

(*b*) The stockinet should not be pulled down too far at the upper end of the plaster This may cause the rolled up plaster to press unduly on the skin

(*c*) The distal extremity of the plaster should not force the toes into dorsiflexion It should be well moulded to the instep but should then be quite straight or in the neutral position

(*d*) The plaster on the dorsal aspect of the foot should reach the cleft of the toes exactly and should neither leave a space nor encroach on the toes Movement of the fifth toe should not be restricted Unless the toes are supported on their plantar aspect they are apt to get contractures As plantar flexion is considerably stronger than dorsiflexion wasting of the plantar flexors is not likely to occur therefore movement in this direction is purposely limited Dorsiflexion of the toes is encouraged throughout

BELOW KNEE PLASTER INCORPORATING PINS

Frequently fractured tibiæ are treated on a screw traction apparatus with Steinmann pins through the upper end of the tibia and through the os calcis The pin apertures are sealed off by gauze and mastisol and the plaster is then applied to the skin directly The distance from the upper to the lower pin is measured precisely and two 4 in strips of exactly the required length are applied They should lie comfortably with their upper and lower limits abutting against each pin and should meet exactly in front and behind any redundant part being removed They are bandaged together by a 4 in plaster bandage and a 2 in bandage incorporates the pins above the limit of these strips by a figure-of-eight movement both in front and behind A posterior strip is applied from the upper pin to the tips of the toes This is made 1 in longer than is necessary and is doubled back over the foot which makes for additional strength The plaster is then finished as in the usual below knee plaster Corks are applied to the pins and incorporated in the plaster

Fig 474
Above knee plaster Note patient co-operating by holding roll of stockinet and wool at upper end.

Fig 475
Complete above knee plaster

Felt over dorsum of foot, strip in position cut through one third of width on each side at knee and ankle

ABOVE-KNEE PLASTER

This is applied over stockinet It should reach the upper limit of the thigh Stockinet 2 in in width is lightly packed with wool and the resulting sleeve of wool is applied round the upper limit of the thigh A conscious co-operating patient can assist by holding it in position (Fig 474) The

plaster differs in no other respect from the below-knee plaster, except that the posterior strip reaches from the upper limit of the thigh to the toes, and should be carefully moulded round the knee-cap (Fig 475)

Precaution—The plaster should be applied with the limb in the neutral position If it is applied with the limb widely abducted, it may be found that it presses in the pubic region when the limb is adducted again If it is applied when the hip is flexed, it may be found that it presses posteriorly when the limb is in the neutral position

Walking plasters—The patient can walk by means of a Böhler iron or by means of sorbo pads The Böhler iron (Fig 476) is moulded to the contours of the plaster by a spanner It should extend 1½ in beyond the end of the plaster, and should be in the central axis of the limb It is attached by means of a 3-in plaster bandage applied in the form of a figure-of-eight, and both limits of the iron should be connected by plaster by a further figure-of-eight across the under surface (Fig 477)

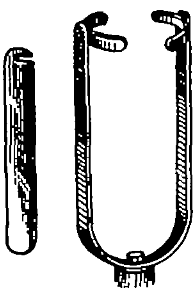


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Fig 476

Bohler iron with spanner for bending it

Fig 477

Bohler iron being applied by figure of eight bandage It should be exactly in the long axis of the limb This illustration shows that it is placed a little too posteriorly

SINGLE HIP SPICA

This is probably the most difficult plaster to apply correctly, with the possible exception of the shoulder plaster A single spica may be sufficient, but both limbs may have to be included The patient is placed on the orthopædic table, and his feet are secured to the foot-pieces by plaster-of-Paris bandages or strapping (Fig 478) If an orthopædic table is not available, an alternative method is to rest the shoulders on a support, consisting of a wooden box 6 in in height, while the pelvis is supported on

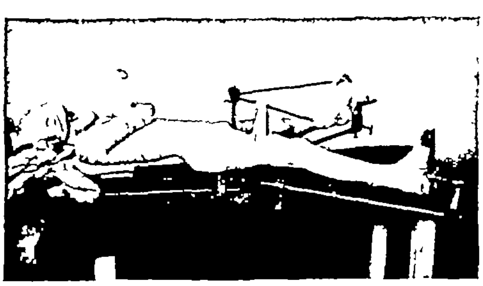


Fig 478

Hip spica applied on orthopædic table for delayed union of femur Note webbing support to prevent backward angulation

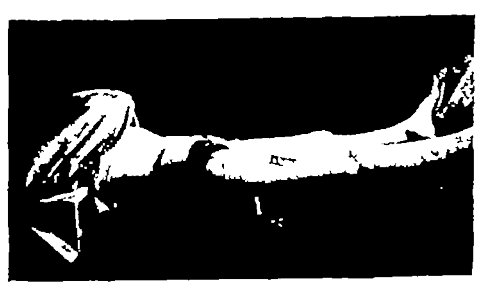
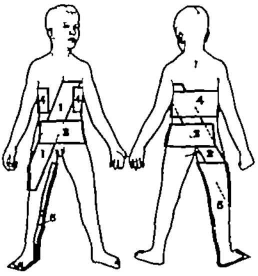


Fig 479

Hip spica applied on shoulder and pelvic supports

a metal pelvic support (Fig 479) This will necessitate each leg being held by an assistant The arms are flexed at the elbow and bandaged together

Application—Stockinet is applied to the body and leg and connected by strapping One layer of wool is bandaged to the pelvis and firmly secured by a 6 in cotton bandage Extra wool is applied over the anterior superior spines If a really tight fitting plaster is required one layer of felt half an inch thick over the anterior superior spines will be sufficient Plaster bandages are then applied evenly no area being unduly neglected When a thickness of approximately a quarter of an inch has been reached reinforcing strips are laid on Five strips (Figs 480 and 481) will be required 6 in wide and 2 ft long These are applied as follows —



Figs. 480 and 481

Hip spica. Diagrammatic application of strips. These are the minimum number More may be applied if considered necessary

1 On the anterior aspect of the limb from the knees to the opposite costal margin (Fig 482)
2 Similarly on the posterior aspect
3 Round the lower margin of the plaster on the opposite side from the groin to the gluteal region (Fig 483)

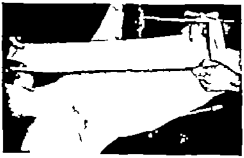


Fig 482

First anterior strip being applied.

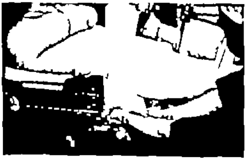


Fig 483

Third strip round the lower margin of the plaster on the opposite side

4 Posteriorly over the lower ribs
5 From the gluteal region to the lower limit of the plaster 6 in above the ankle or if the foot is being included, to the tips of the toes The foot and ankle if not included should be strapped with elastoplast to limit swelling

The strips should not be too thick, and should lie smoothly When bandaged on, no air should be left between the strip and the plaster One aluminium strip may be applied It passes from the upper limit of the plaster on the affected side along the lateral aspect to just above the knee (Fig 484) It should be moulded to fit the plaster, and covered with one layer of plaster bandage before application

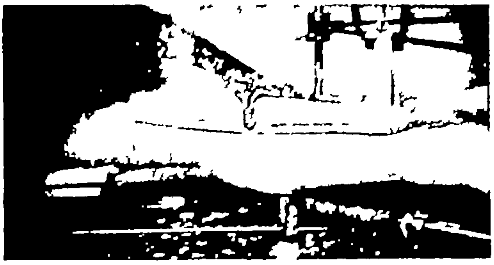


Fig. 484
Aluminium strip down outer aspect

Trimming the plaster—The correctly applied plaster spica should extend upwards towards the axilla on the unaffected side, and downwards well below the crest of the ilium It should be trimmed in the shape of a V or U over the epigastrium for respiration (Fig 485) The posterior window can be cut in two ways, either a narrow triangle which just exposes the natal cleft, or a wide arch, the edges of which are clear of the tuber ischii The tuber ischii should be either supported by plaster or completely free, and the plaster should not be trimmed so that the tuber ischii rest on its edge A

Fig 485

Area for trimming mapped out with indelible pencil

Fig 486

Stockinet cuffed back and secured by strapping Plaster of Paris is better, as strapping will not stick until the next day

narrow triangular aperture extending to the upper limit of the cleft is to be preferred After trimming, the stockinet is cuffed over and secured by strapping or a plaster bandage (Fig 486) In turning the patient to trim the plaster behind, the plastered limb should be kept uppermost, and not used as a lever on which to turn the patient This point should be observed in nursing

DOUBLE HIP SPICA

This is made in a similar way (Fig 487), but the limbs should be connected by a cross-bar of plaster This is made by twisting a strip several times, bending each end to a length of 4 in and bandaging it on to both thighs with a figure-of-eight plaster bandage (Figs 488, 489, 490, 491, 492, 493)

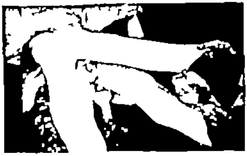


FIG 487

Double hip spica. Strips being applied to opposite leg

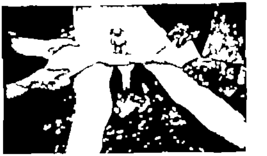


FIG 488

Method of making cross-bar

FIG 489

Cross-bar applied and strengthened

FIG 490

Area for posterior window mapped out

FIG 491

Covering the blind spot

The weak spot in plaster spicas is between the pelvis and limb behind. Plaster bandages must be brought well towards the middle line over the gluteal region

FIG 492

Single hip spica. Note that the plaster comes well under the tuber ischii, the V shaped window for nursing, and well down over the opposite iliac crest.

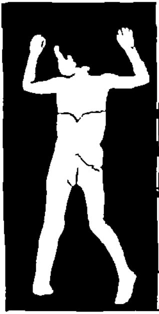


FIG 492

FIG 493

FIG 493

Single hip spica. The plaster extends over the lower ribs and is moulded carefully over the crests of the ilium. The knee is in the neutral position and not in valgus. Note the V shaped window for the epigastrium

The strips should not be too thick, and should lie smoothly. When bandaged on, no air should be left between the strip and the plaster. One aluminium strip may be applied. It passes from the upper limit of the plaster on the affected side along the lateral aspect to just above the knee (Fig. 484). It should be moulded to fit the plaster, and covered with one layer of plaster bandage before application.

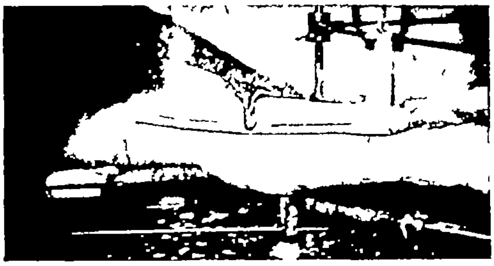


FIG. 484
Aluminium strip down outer aspect

Trimming the plaster—The correctly applied plaster spica should extend upwards towards the axilla on the unaffected side, and downwards well below the crest of the ilium. It should be trimmed in the shape of a V or U over the epigastrium for respiration (Fig. 485). The posterior window can be cut in two ways, either a narrow triangle which just exposes the natal cleft, or a wide arch, the edges of which are clear of the tuber ischii. The tuber ischii should be either supported by plaster or completely free, and the plaster should not be trimmed so that the tuber ischii rest on its edge. A

FIG. 485

Area for trimming mapped out with indelible pencil

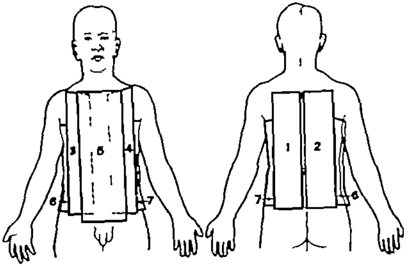
FIG. 486

Stockinet cuffed back and secured by strapping. Plaster of Paris is better, as strapping will not stick until the next day

narrow triangular aperture extending to the upper limit of the cleft is to be preferred. After trimming, the stockinet is cuffed over and secured by strapping or a plaster bandage (Fig. 486). In turning the patient to trim the plaster behind, the plastered limb should be kept uppermost, and not used as a lever on which to turn the patient. This point should be observed in nursing.

DOUBLE HIP SPICA

This is made in a similar way (Fig. 487), but the limbs should be connected by a cross-bar of plaster. This is made by twisting a strip several times, bending each end to a length of 4 in. and bandaging it on to both thighs with a figure-of-eight plaster bandage (Figs. 488, 489, 490, 491, 492, 493).



FIGS. 496 and 497

Spinal plaster. Diagrammatic application of strips. Strips 8 and 9 superimpose strips 3 and 4. Strip 5 is folded back on itself over the chest.

latter being 6 in longer than the length of the patient for doubling back over the chest. For greater speed these strips should be made in advance from dry proprietary bandages.

Application.—Plaster is applied over two layers of stockinet and felt. A layer of felt 4 in wide and ½ in thick extends round the iliac crests until it meets over the centre of the abdomen where it is secured by strapping or if preferred is stitched to the stockinet. A second strip of felt 8 in by 4 in. by ½ in is strapped to the upper part of the chest (Fig 498) and a third strip 2 in wide extends from the upper margin of the felt over the crest of the ilium to the upper limit of the plaster which is usually the third or fourth dorsal vertebra (Fig 499). Six inch plaster bandages are applied carefully and smoothly. When a depth of ¼ in has been reached two plaster strips are applied posteriorly extending from the upper to the lower limit of the plaster from the fourth dorsal vertebra to 3 in below the crest of the ilium. They lie side by side and meet in the middle line. Two similar strips are placed anteriorly but their inner margins are separated by 2 in. The 8-in strip is applied from the pubis to the upper part of the chest (Fig 500). It is then folded back for a distance of 6 in. Its upper margin lies in contact with the clavicles. The plaster bandage does not actually travel over the shoulders but the plaster is carefully moulded round the neck and particularly in the

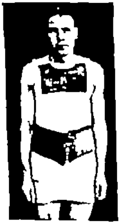


FIG 498

Two layers of stockinet and felt *in situ*

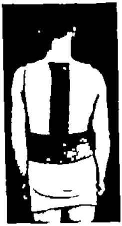


FIG 499

Posterior view

The felt and stockinet can be sewn together or strapping can be used

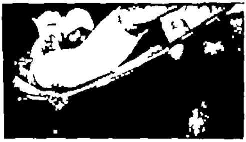


FIG. 500

Eight-in. strip being applied.

SPINAL PLASTERS

These comprise —

1 Spinal plaster or spinal jacket for fractured spine
2 Spinal beds

SPINAL PLASTER OR SPINAL JACKET FOR FRACTURED SPINE

This is applied in hyperextension The two-table method of Watson-Jones may be used (Fig 494) Neither the patient's buttocks nor his shoulders should be supported by either table, or full hyperextension will not be obtained Watson-Jones' method acts chiefly on the lumbar region An alternative method which is particularly efficacious for reduction of fractures of the dorsal spine, is illustrated in Fig 495 Further reduction may be obtained by an injection of Pentothal during the application of the plaster Of the two methods the latter is usually the more satisfactory Of necessity the application of the plaster in the two-table method taxes the endurance of the patient, he undoubtedly suffers pain, and this cannot be obviated, as his co-operation is necessary

FIG 494
Position for application Both the pelvis and the shoulders must be clear of the table

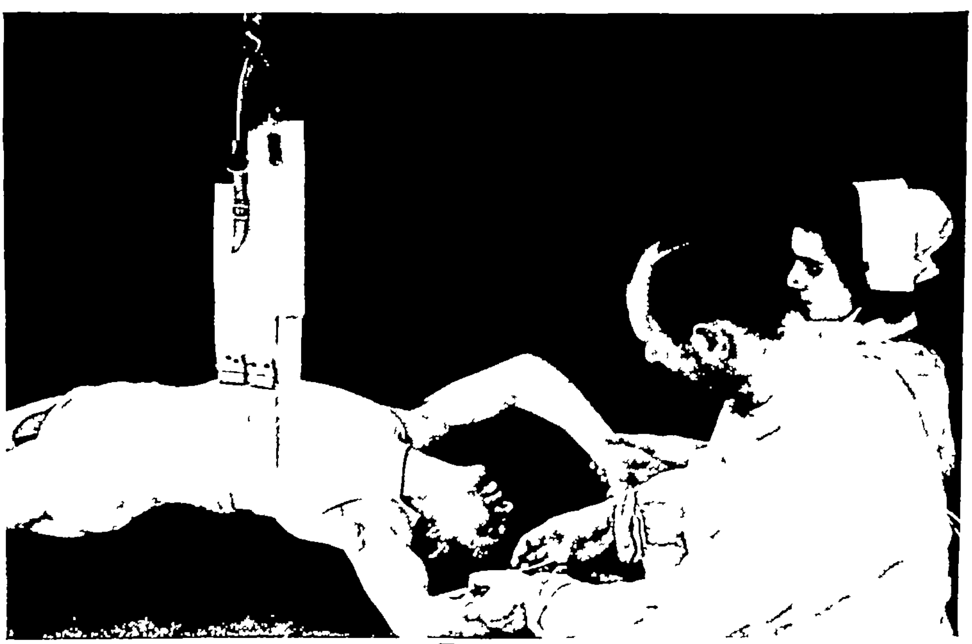


FIG 495
Position for applying plaster for fracture of the dorsal spine Pentothal causes relaxation and aids hyperextension and reduction

Good team-work is essential for speedy application, and as plaster sets in just under ten minutes, no longer should be taken Nine strips (Figs 496 and 497) will be necessary, eight of them 6 in in breadth and one 8 in , the

(b) The plaster should extend up to the fourth dorsal vertebra behind A common error is to imagine that it is not important to bring the plaster up high behind but it must be brought up sufficiently high to maintain the patient in hyperextension

SPINAL PLASTER BED FOR FRACTURED SPINE WHERE A JACKET CANNOT BE APPLIED FOR *SPINAL PARALYSIS, DISEASE OF THE SPINE, ETC.*

Sheets of muslin impregnated with wet plaster powder are used reinforced by plaster strips The bed usually extends from the shoulders to just above the knees but the head or the legs may be included if necessary The bed illustrated in Fig 505 extends from the head to just above the knees Measurements are previously taken of the determined length and also from acromion to acromion Eight inches are added to both length and width and if the head is being included its shape is roughly cut out (Fig 506)

Fig 505

Preparation of table for plaster bed Small sandbag for head; pillow in centre sandbag to separate feet. Greased mackintoshes separated by 4 in. These will be pulled out at the end, and will separate the patient from the bed without discomfort.

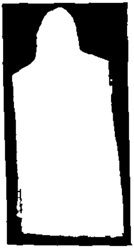


Fig 506

Twenty sheets of muslin cut out roughly to the shape of the head and trunk.

Application—The patient lies on his face on two mackintoshes separated from each other by 4 in a sandbag between his feet and his knees separated by 8 to 12 in The mackintoshes are pulled out on the completion of the plaster and free the bed from the patient with the least inconvenience to the patient The forehead should rest on a very small sandbag and the patient should be well greased with vaseline (Fig 507) An ordinary sized basin is half filled with plaster powder and warm water is poured in the powder being mixed to a paste until it reaches the consistency of cream (Fig 508) Two layers of muslin are grasped by the corners and completely immersed until they are impregnated with plaster (Fig 509) They are then lifted out and placed over the patient (Fig 510) The first layer is the most important and should be carefully smoothed out until no wrinkles are left Round the neck the muslin should be cut through on each side until it lies accurately (Fig 511) The assistant at the upper end should place his hand on the small of the patient's back while the assistant

Fig 507

Position of patient for spinal plaster bed

infraclavicular hollows (Fig 501) The lower extremity of the plaster is also carefully moulded over the pubis and in the groins Four more 6-in strips are applied two on the lateral aspects passing down from each axilla and two on the anterior aspect 3 in apart (Fig 502)

Fig 501

Careful moulding in the clavicular region

Fig 502

Lateral strip being applied

Trimming the plaster—When the plaster has set the patient is turned on his back, a pillow being placed in the concavity of the spine, and the area for trimming is mapped out with an indelible pencil Ample room must be left for the arms and a V-shaped aperture is made for the neck The plaster should be trimmed away until it does not encroach on the flexed hips (Fig 503), and it will be found that this trimming has to be carried laterally farther than would be expected The plaster must also be trimmed behind, so that the patient can sit without discomfort An epigastric window can be mapped out for respiration (Fig 504), but this should not be removed until the next day, although advantage may be taken of the fact that the plaster is soft to cut through two-thirds of its circumference This can be done by cutting two arcs, which can easily be connected If kyphosis is present and it is impossible to reduce it completely, a narrow longitudinal window should be cut over it, this should not extend laterally to the edges of the posterior strip of felt

Fig 503

Complete spinal plaster Ninety degrees of flexion at the hip joint is allowed

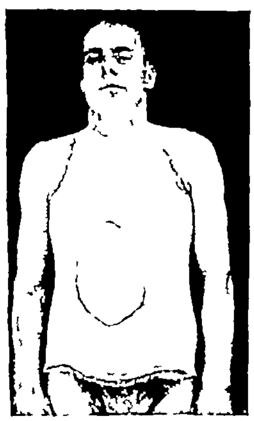


Fig 504

Complete spinal plaster The stockinet has not yet been cuffed back Note that the plaster reaches well up to the clavicles

Precautions—

(a) The plaster should extend up to the clavicles and be carefully moulded into the infraclavicular hollows This is very commonly neglected and is where the maximum correction should be obtained

is now used and the remaining sheets are applied (Fig 514) It will be found that no more than three pairs of sheets can be used for each basin Twenty sheets in all are as a rule ample It is an error to cut the plaster between the legs It should be allowed to lie on the table between the legs and should be folded back above the knees if the feet are not included When the window for nursing is cut a bar of plaster is left connecting the legs which makes for additional strength (Fig 515) The plaster is lifted off by three people (Fig 516) the mackintoshes first being pulled out It should be baked near a furnace for twenty four hours and then mounted on a wooden frame as in Fig 517 supports for the arms a mirror and a book rest being added The plaster can be lined with sorbo or felt, and stockinet sewn over it Sorbo is more comfortable for the patient but felt is cheaper If the patient is incontinent a sheet of jaconet can be inserted under the buttocks and the head of the frame lifted slightly so that secretions will run downwards

Fig 514
Plaster being finished off by dry sheet of muslin to make it smooth. This is lifted off afterwards.

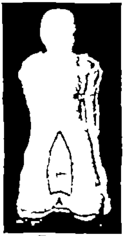


Fig 515
Complete plaster bed —posterior view Note window for nursing mapped out and cross-bar at A, which makes for additional strength.

A plaster bed made by this method is very strong and should easily last a year or more Its strength is increased by the constant rubbing in between the application of sheets

Fig 516
Plaster being lifted off carefully The mackintosh sheets have been pulled out from below

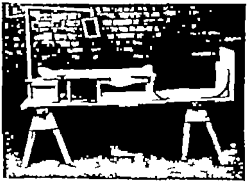


Fig 517
Plaster bed mounted on wooden frame The lower limbs have not been included.

especially at areas like the neck and the buttocks An anterior plaster shell may be made in a similar manner so that the patient can be turned on his face without disturbing his immobilization

at the lower end pulls the plaster down between the legs If this is not done the traction on the plaster may cause it to rise up from the loins The plaster should be carefully moulded over the iliac crests and along the ribs (Fig

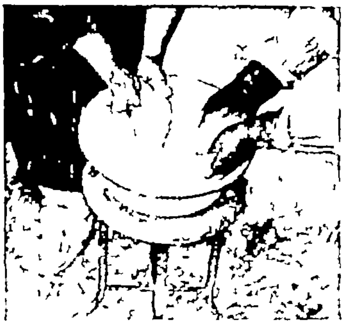


Fig 508

Mixing the plaster paste

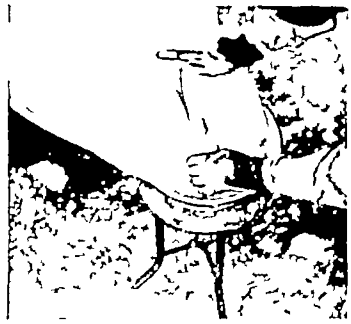


Fig 509

Double sheet of muslin being fed to become impregnated with plaster paste

Fig 510

Wet sheet being laid on patient

Fig 511

Sheet being cut through in region of neck for accurate apposition

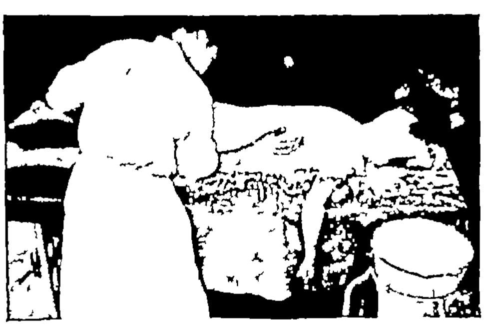


Fig 512

Careful moulding over crests of ilium and loins

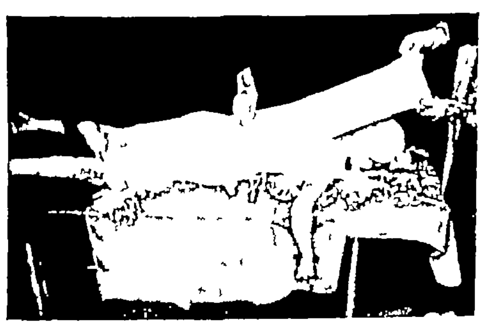


Fig 513

Lateral strips being applied

512) This application is repeated a couple of times with successive layers of plaster, making six layers in all Strips should then be used They are placed as follows Longitudinally on the outer aspect of the plaster throughout its entire length (Fig 513) longitudinally from just above the knees to the loins , and transversely across the shoulders A fresh basin of plaster

CHAPTER LV

METHODS OF APPLYING EXTENSION TO THE LIMBS

BY ADHESIVE STRAPPING

THE chief criticisms levelled at strapping extension are —

(a) That irritation of the skin follows prolonged application of strapping and

(b) that sufficient tension cannot be applied by skin traction alone

Regarding the first criticism ordinary zinc-oxide strapping when left in position for several weeks often produces painful irritation blistering and superficial ulceration of the skin which can be relieved only by removing the strapping If, however a non irritative material is used such as the ordinary Leslie s Holland strapping or the Flexoplast orthopædic strapping skin irritation does not occur This in the case of Hospital strapping is due to the non irritating composition of the adhesive material of which it is made

Colophony	100 gm	Applied on a strong canvas foundation
Lead plaster	850	
Hard soap	50	

When this strapping is applied to the skin correctly it can be left in place quite safely for six to eight weeks when powerful extension is being used

Regarding the second criticism the supposed inefficiency of this type of extension is not a valid objection Sir Robert Jones and those trained by him have proved that skin traction is adequate providing various nursing details are attended to carefully No difficulty is experienced in attaching sufficient weight to obtain full length of a fractured limb indeed, it is a comparatively simple matter to produce overlengthening by this means if such is desired

The outstanding advantage of strapping as a medium for applying extension is its entire freedom from the dangers which although slight are inherent in any type of skeletal traction

For many years strapping extension has been used with success in the treatment of fractures of the shaft of the femur indeed, the value of the method reaches its zenith in these cases Details of its application will therefore be presented.

Preparing extension straps—Straps must be of the proper length extending from 3 in above the site of the fracture to just below the malleoli

REMOVING PLASTERS

Plaster shears are probably the favourite instrument, but surgeons have individual preferences It is convenient to have a variety of plaster-removing instruments

In removing a plaster from a limb it is important to cut it through completely on both sides, so that the top lid can be lifted off, especially if the plaster has been applied to immobilize a fractured limb Cutting through one side only and breaking the plaster open is to be condemned It is possible to break down union or even fracture a bone by so doing Soaking the cast will always render it soft, so that it can be cut through by a scalpel easily

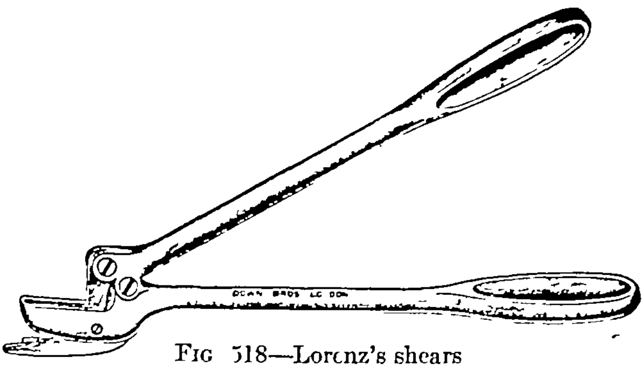


FIG 518—Lorenz's shears

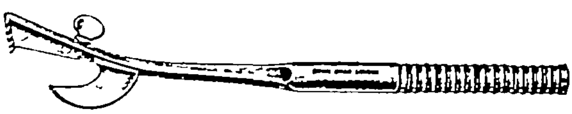


FIG 519—Bristol model plaster cutter

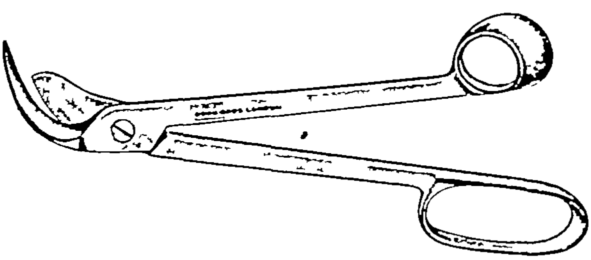


FIG 520—Plaster cutter with curved blade

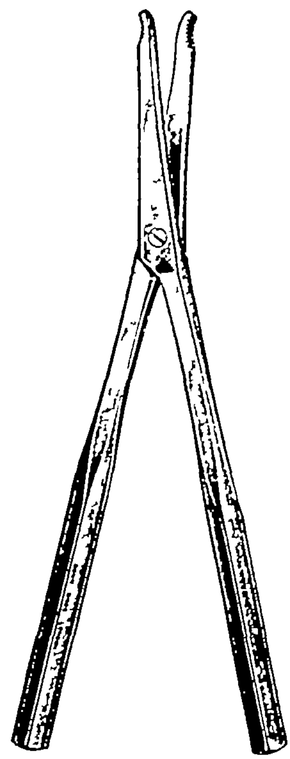


FIG 521
Spreading forceps

An electrically driven plaster remover is not only inefficient but is also dangerous An ordinary meat saw is a most efficient instrument and will remove the thickest plaster It should be used in a series of zigzag cuts

The removal of plasters may be rendered easier by the incorporation of metal strips which can be cut down upon, or by the inclusion of piano wire which will actually cut through a thin plaster, but it is, however, doubtful if these measures are worth the trouble involved when applying the cast A further important point is that the surgeon who puts on the plaster is seldom the person who takes it off

Post-operative plasters should have a window cut in the plaster at the time of operation This can be completed when the sutures are due to be removed and will save both the patient and the surgeon trouble

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GIRDLESTONE, G R *Lancet*, 1940, **2**, 387 SCHNEK, F "The non padded plaster cast" Vienna, 1932

malleoli (Fig. 525). At this point the gauze bandage ceases to be applied *over* the strapping: it is passed beneath the non-adherent attachments of the wick tapes. Thus the extremities of the straps are separated from the skin by two or three turns of the gauze bandage, which prevents pressure on bony points.

Fig. 526

Showing method of passing the extensions around the bar of Thomas splint and tying them over the terminal W

It should be noted particularly that cross-strapping is never employed. Encircling plaster bands are liable to produce swelling and oedema, a condition which predisposes to muscle and joint rigidity. A soft bandage is free from these baneful possibilities and is perfectly efficient.

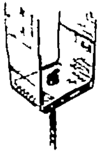

Fig. 527

A wooden spreader for incorporating in strapping plaster ready for application

If the limb is to be treated on a Thomas splint, a piece of strong bandage is threaded through each of the wick tape loops (see Fig. 525) and twisted into a cord. One cord passes in front of the outer bar, the other passes behind the inner bar (Fig. 526). Efficient extension is maintained by tying the two cords tightly over the concavity in the terminal cross-piece of the splint (Fig. 526). When straps are to be used on a limb which is not being treated on a Thomas splint, a wooden spreader is an advantage. The wooden spreader can be incorporated in the strapping plaster before its application (Fig. 527), or if the pattern shown in Fig. 528 is available it can be buckled on to the standard straps described above.

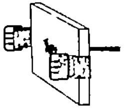

Fig. 528

A wooden spreader for buckling to extension straps attached to the limb already

BY SKELETAL TRACTION

By this is meant traction applied directly to the bone. When it is desired to apply extension to the lower limb the point of traction is a matter of choice: the tubercle of the tibia and the os calcis are each much better for this purpose than the condyles of the femur. Because of its simplicity and ease of insertion, Steinmann's nail (Fig. 529) combined with Böhler's swivel stirrup is preferable to Kirschner's wire. It is true that the nail makes a bigger hole in the bone than the wire, but this disadvantage is more than offset by the tendency of wire to cut out and the liability of drills

Fig. 529

Steinmann nails (*London Splint Co.*)

Two identical sections of the required length are cut from the broad sheet of strapping (Fig 522) supplied by the makers They are wide at the upper end so that after application they embrace the limb, but they must not touch each other either in front or at the back As the straps extend downwards they become narrower, the better to accommodate themselves to the shape of the limb, and in order that they may fit the varying contour, cuts of ½ to 1 in are made on both sides of the strapping (Fig 523) The lower pointed sides of the strapping are infolded twice longitudinally so as to ensure a thick, strong extremity Lastly, the free ends of a loop of wick tape having been incorporated within the aforementioned borders, these are held securely in place by stitches embracing all sections of the strapping and the wick tape (Fig 524)

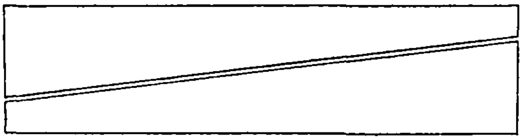

FIG 522
Diagram to show method of cutting strapping so that the two strips may be obtained from one length of material (*Farquharson*)

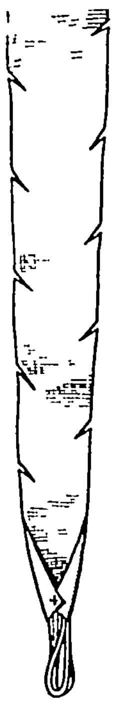

FIG 523
Cuts are made at the side of the strapping, the better to mould it to the contour of the limb

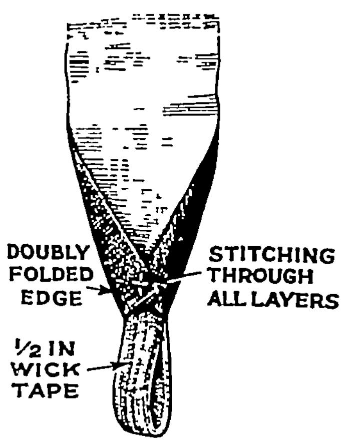

FIG 524
Method of affixing lamp wick loops to the extremity of a strap

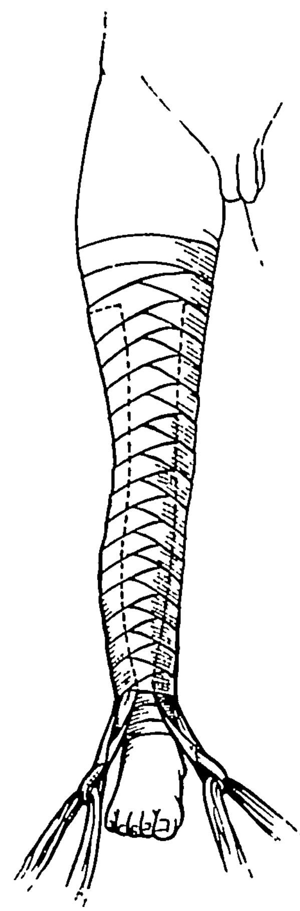

FIG 525
Showing how the gauze bandage is applied over the straps and then under the straps in the region of the malleoli The method of attachment of a strong bandage through the loops of wick tape is also depicted

Application of the straps—Shaving the limb is unnecessary indeed, it is to be discouraged, for newly shaved skin is tender and more liable to resent trauma The plaster is heated sufficiently to soften its adhesive surface The straps are applied evenly on either side of the limb, usually the inner strap being slightly anterior to the outer On no account must they overlap, either in front or behind The straps are held in position by a loosely applied gauze bandage which extends over the whole of the strapping from its upper border to a point 2 in above the base of the

traumatic surgery Its main indication is in cases of compound fractures of the phalanges where the corresponding flexor surfaces of the fingers are wounded

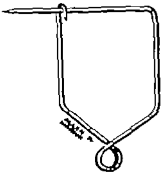

Fig 333

Brock s pin

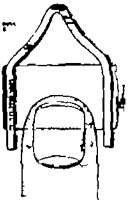

Fig 334

Stirrup for finger traction. The pulp of the finger is transfixed by a silk worm gut suture carried on a straight needle This is passed through the four holes in the stirrup and tied as shown (F arquharson)

A stainless steel wire 0 5 mm thick is pushed transversely through the pulp a quarter of an inch proximal to its tip just in front of the medial and lateral borders of the finger nail Brock s pin (Fig 333) or Farquharson s pulp traction frame (Fig 334) are both very efficacious for carrying out this type of traction Pulp traction can be used in conjunction with the banjo Cramer wire splint (see p 652)

FIRST-AID MEASURES FOR APPLYING EXTENSION TO THE LOWER LIMB

Particularly in cases of compound fracture of the femur the best practice is to apply a Thomas splint before slitting the trousers or attending to the

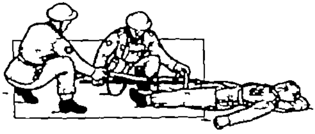

Fig 335

Showing how efficient extension can be applied to a fractured femur

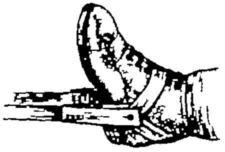

Fig 336

Williams extension brace applied over the boot

wound Extension on the booted foot can be achieved in several ways —

(a) A clove hitch around the ankle (Fig 335) This emergency expedient is sometimes followed by pressure necrosis of the skin (Jeffrey)

(b) Williams extension brace (Fig 336) made of strong cloth strapping is a great improvement on (a)

(c) A skewer through the boot is efficient but takes time to insert it is not easy to carry out the necessary transfixion in the black-out

Fig 337

Picton spring clip

(d) Picton s spring clip (Fig 337) was made originally by one of Picton s ambulance men This spring clip of strong steel wire can be fixed easily into the boot heel and provides a fulcrum for efficient extension

to get out of order and spanners not to fit other instrument-makers' nuts. A further important point is the risk of infection, which is increased by movement of the foreign body in the bone; movement is obviated by the swivel on the Böhler's stirrup (Fig. 530).

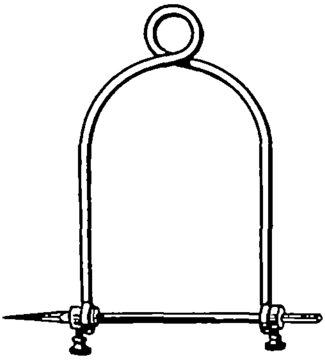

Fig. 530
Böhler's swivel stirrup affixed to a Steinmann's nail

The insertion of a Steinmann's nail can be performed under local anæsthesia, but, especially if a fracture has to be manipulated, nitrous oxide or intravenous anæsthesia is preferable.

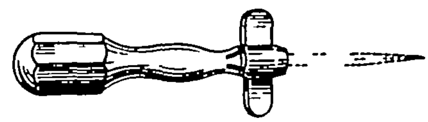

Fig. 531
Max Page's nail holder

Insertion of Steinmann's nail.—It is only necessary to paint the skin with iodine, nick it with a scalpel and, with the nail in a holder (Fig. 531), hammer it straight through the bone until it appears under the skin of the other side (Fig. 532). This is then incised with a scalpel, the nail tapped onwards for an inch or two, and the stirrup screwed into position.

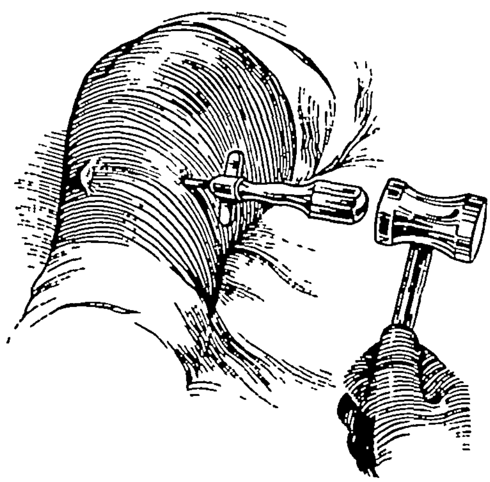

Fig. 532
The nail is driven through the bone until its point appears under the skin, which is nicked with a scalpel

The technique of inserting the nail in various situations is as follows:—

(*a*) Through the tubercle of the tibia.—A 15-cm. by 4-mm. Steinmann's nail is driven through the bone ¾ in. behind its crest.

(*b*) Through the os calcis.—The nail is made to pass through the os calcis two fingers' breadths behind and below the malleoli.

In the upper limb skeletal traction is not often necessary. A 4-mm. nail or Kirschner's wire can be driven through the olecranon process and a fracture dislocation of the humerus reduced on a screw traction apparatus. Occasionally a direct pull on the metacarpals is required and the inner four can be transfixed with a nail or wire.

Removal of the nail.—The stirrup is removed and the nail entrance and exit wounds, together with the nail itself, are swabbed with spirit. The nail is then pulled out with pliers. Generally it is loose and comes out easily, therefore no anæsthetic is necessary. Again the wounds are swabbed with spirit, after which they are covered with suitable pieces of flexible adhesive plaster dressing. The dressings should remain in place for ten days or a fortnight, by which time healing is complete.

BY PULP TRACTION

Pulp traction is considered an obsolete method by some surgeons, but there can be no doubt that it still retains a very useful place in

CHAPTER LVI

THE USE OF THE THOMAS' SPLINT

INTO the surgical literature of the 1870's Hugh Owen Thomas arrived with an unshakable belief in the value of prolonged, uninterrupted and complete rest in the treatment of diseased and injured tissues. He had been deeply influenced by the writings of Hilton on "Rest and Pain," and his experience in the treatment of fractures and diseases of joints satisfied him as to the truth of these teachings.

Thomas was fortunate in possessing the mechanical ability to devise simple and efficient splints by which these principles could be carried out and, because of the care displayed in their construction and the prolonged testing to which each splint was subjected, most of them are still in daily use.

The long series of splints devised by Thomas includes the one which is generally described as the Thomas' Splint although originally called by him the "bed knee splint" (Fig. 539). There is no particular reason why this apparatus should have received the title of Thomas' splint rather than any of the others. Its essential feature is its simplicity both of manufacture and of application.

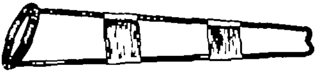

FIG. 539
The splint known as Thomas' was called by the originator the "bed knee splint."

CONSTRUCTION

Thomas' own description is as follows: The splint is made of round bar iron of good quality, iron being preferable to steel on account of its greater rigidity, the thickness of the iron rods varying according to the size of the patient. Thus for a splint to fit a child, bar iron of $\frac{5}{16}$ in. is sufficiently strong, while for an adult patient the metal should be of $\frac{3}{8}$ in. gauge. The splint is manufactured in two sections, each of which is made of the same thickness of iron rod: the first an oval ring as in Fig. 540 into which are welded two other straight sections of the iron bar at opposite points of the oval as in the diagram. The inner bar is fused to the more open section of the oval at an angle of 120°, while the outer bar joins the outer margin at an angle depending on the size of the ring. These two straight bars continue downwards approximating slightly to each other for a distance of 6 to 9 in. beyond the full length of the limb to be treated, where the two lateral bars are fused to each other in the middle line in a junction somewhat like the letter W, which permits the fixation of the extension tapes.

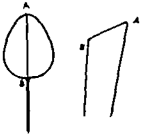

FIG. 540
Lateral and anteroposterior views of Thomas' bed knee splint.

(e) The Millbank clip (Fig 538) was invented by Monro, and is likely to become a standard device It prevents foot drop and rotation of the limb and can be applied by anybody in a few seconds

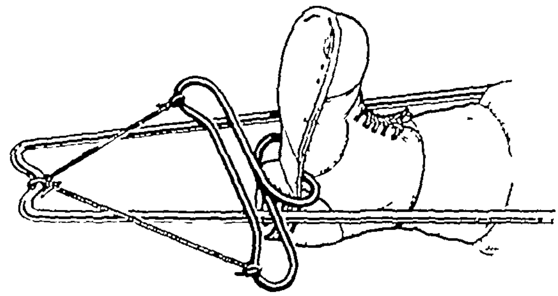

Fig 538
The Millbank clip

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traction on the limb the whole body may be used as the counter extending force

In using the Thomas splint the extension or as it should be more correctly described the fixation of the limb can be applied adequately in most instances by means of the ordinary canvas backed strapping usually described as hospital strapping This is non irritating and may be left in position for six or eight weeks Occasionally on account of skin destruction it is impossible to use strapping and skeletal traction must be applied through the tuberosity of the tibia or some other suitable bony point

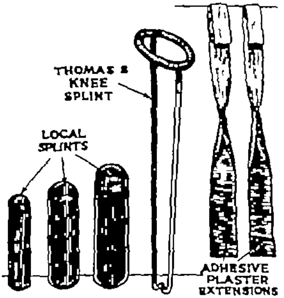

FIG 543
Essential requirements for the treatment of fractured femur by Thomas method.

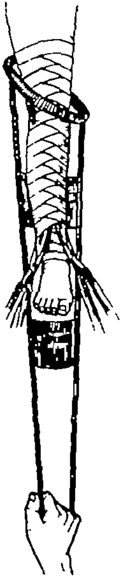

FIG. 544
Introducing the limb through the ring of Thomas knee splint

If the extension straps from such skeletal fixation are tied at the W end of the splint as when strapping is used then Thomas theory of complete rest and fixation is being employed but if as is so frequently seen weight and pulley extension is employed at the same time then the Thomas splint is being used simply as a hammock for the broken bone

Application of a Thomas splint (Fig 543)—The application is a simple matter when the extensions have been bandaged in position (see p 618) steady traction is applied to the limb the ring of the splint is threaded over the extensions and the foot and is then passed up into position under the ischial tuberosity

As a rule under anæsthesia there is little difficulty in obtaining full length of the limb in a few minutes provided that the pull is constant and the broken femur is supported and kept in correct alignment When full length has been obtained the wick or bandage ends of the extension straps are firmly knotted round the depression at the foot of the splint Any tendency towards loss of alignment of the limb by rotation of the lower fragment internally or externally can easily be prevented by the arrangement of the extension straps round the bars of the splint If as generally happens the foot shows a tendency towards external rotation the outer strap should first be passed over the front of the outer bar while the inner strap passes behind the bar

The metal framework forms the basis of the apparatus, whose measurements are simple, the length, as given previously, being in the adult 9 in longer than the limb to be treated, while the circumference of the oval ring is 1½ in larger than the circular measurement of the thigh just below the gluteal fold The addition of 1½ in to the circular circumference of the limb allows space for the padding which is subsequently added to the ring, and also for the obliquity with which the ring is applied Although the angle between the inner bar and the oval ring is 120° in the uncovered state of the splint, the addition of the felting and leather lining reduces this angle

THOMAS' SPLINT IN THE TREATMENT OF FRACTURED FEMUR

Of the variety of uses of Thomas' splint, reference will now be made to its inestimable value in treatment of fractures of the femoral shaft and condyles Thomas' method is based on his belief that when the broken limb is so controlled as to be completely and continuously at rest, all abnormal muscle spasm disappears and union can then proceed rapidly and efficiently

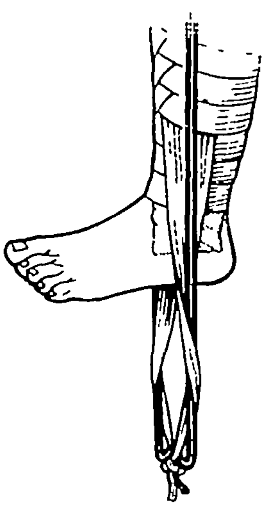

FIG 541

The usual method of maintaining extension in the case of fractured femur treated in a Thomas' splint

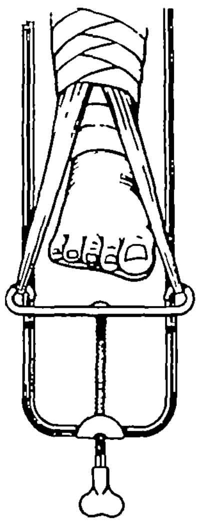

FIG 542

Screw-end attachment, valuable when it is impossible to restore full length of the limb at the first "setting"

To bring his theory into practice the limb is "set" under an anæsthetic, which means that after being pulled to its normal length the limb is so immobilized that secondary muscle spasm is prevented and the tendency to displacement disappears (Fig 541) Occasionally, when the fracture has occurred some days or weeks previously, it is impossible to restore the full length of the limb at the first "setting" The remaining shortening must be overcome gradually To accomplish this—with or without the help of an anæsthetic—the extension apparatus shown in Fig 542 is fastened to the splint end After a few hours further length is gained by pulling firmly on the extensions, followed by fixation as before On each occasion when traction is applied, further length is obtained This process can be repeated every few hours until the full length of the limb has been attained Fixation must be continued until union is complete

This belief of Thomas in the efficiency of complete immobilization contrasts directly with the other view of fracture treatment, in which the shortening of the limb and the overriding of the fragments are corrected by tiring out the contracted muscles by weight extension, the theory being that the greater the spasm the more weight should be applied until the spasm is overcome By this means full length of the limb can be obtained, but the method is open to the grave objection that unnecessary prolongation of the period of such traction can only lead to overextension of the limb and separation of the fragments of the broken femur

Rationale—In Thomas' method the ischial tuberosity forms a secure non-vulnerable counter pressure point, whilst in the method of continuous

angle that some of the ligaments have been overstretched (Fig. 547). It may be stated as a rule that prolonged fixation of a normal joint with normal

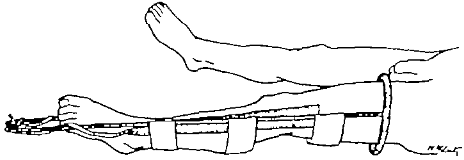

FIG. 547

Incorrectly applied splint. Most of limb below level of splint bars. Extension tapes loose. No support for back of leg and thigh. Hyperextension of knee. Ring of bed knee splint half way down thigh. Leg externally rotated.

musculature and normal circulation will not produce troublesome rigidity if the fixation has been carried out in a position of slight flexion.

When a compound fracture of the femur is complicated by the presence of a discharging wound on the posterior aspect of the thigh, and if it be considered advisable to dress the wound at intervals, the use of a metal back splint may be impossible, or at least inadvisable. In such circumstances adequate support can be given by using a continuous series of canvas slings, which pass between the lateral bars posterior to the limb. These slings, 2 to 2½ in. wide, approximate each other along the area normally supported by the back splint; they are attached laterally by safety pins or paper clips so that one section may be removed for dressing purposes without interfering with the general support.

When the back splint or the canvas slings have been applied, two accessory short metal splints are strapped in position to add still further stability to the area of fracture. These are placed on the anterolateral and anteromedial aspects of the thigh, extending from just below the ring of the main splint to a point 3 in. below the knee joint. They are moulded and padded to fit the normal curves of the limb, and they, with the posterior splint already applied, are strapped together, forming an almost complete metal case.

Limitations of the splint.—The splint is not equally effective in the treatment of all fractures of the femur; it was not designed for the treatment of fractures in the neck or trochanteric region. No fracture of the femur above a line through the lower border of the lesser trochanter with separation of the fragments can be efficiently controlled by a Thomas splint.

Similar objections are not applicable to the treatment of fractures of the lower end of the femur. It is often stated that a supracondylar fracture of the femur must always be treated with the knee bent to a right angle on account of the acute backward tilting of the upper end of the lower fragment. This position of deformity, which is entirely attributable to muscle spasm, can be corrected by a simple fixation as for a fracture of the shaft of the bone. The back pad behind the knee is made slightly larger, the fixation is carried out as already described, and if the method is persisted in intelligently a series of radiographs will demonstrate the restoration of alignment. The correction does not occur immediately, but extends over a

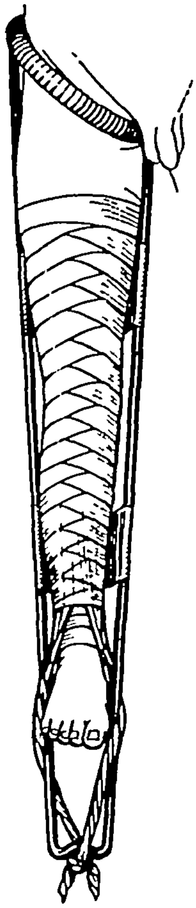

Fig 545
Thomas' splint in position with traction applied

on the inner side (Fig 544) The straps are now passed once or twice round their corresponding bars, in this way removing their pressure from the malleoli without diminishing the efficacy of the fixation By applying the inner extension straps slightly farther forward than the exact centre of the limb, still further internal rotation can be obtained if this is found to be necessary

Accessory splints are now added to complete the fixation, the most important of these being the straight metal gutter back splint, which supports the limb posteriorly from 2 in below the gluteal fold to the lower third of the leg, being held in position by slings passing under it from the lateral bars This splint is so adjusted that when its supporting straps are in position at least two-thirds of the thigh lies in front of the lateral bars of the main splint and only one-third, or even less, remains on their posterior aspect

The importance of this point can be understood by studying the shape of the femur, with its anterior bow which must be restored if the function of the thigh muscles and the normal mechanics of .the knee are to be retained As the thigh is supported in front of the lateral bars of the Thomas splint (Fig 545), the knee-joint must also be maintained in a slight degree of flexion by the use of a pad, 2 to $2\frac{1}{2}$ in in thickness, placed between the knee and the back splint This small degree of flexion of the knee prevents the rigidity of the joint which invariably follows long-continued hyper-extension This point is of the utmost importance, as it seems to be generally accepted that prolonged fixation of a joint produces crippling rigidity There is no doubt that crippling stiffness may follow prolonged fixation of a joint, but the rigidity is not attributable entirely to the cessation of movements If a joint and its periarticular tissues are normal, and possess a normal circulation, even very prolonged fixation of that joint can only produce troublesome rigidity when the fixation has been carried out at such an

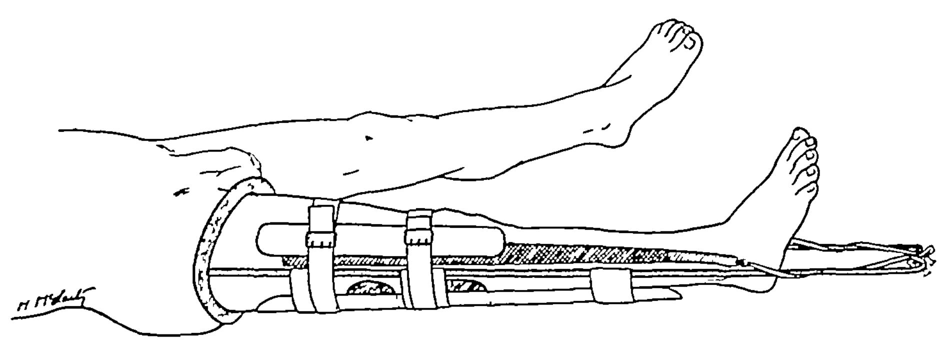

Fig 546
Correct application of the Thomas' splint Three quarters of limb above level of bars of splint Long gutter back splint with pad behind knee and pad beneath site of fracture to preserve slight flexion in knee and normal anterior bow of femoral shaft Ring fitting right into groin and taking pressure on ischial tuberosity

anus and often with the urethra and at times even taking pressure on the anterior superior spine of the ilium

If it is impossible to obtain a Thomas splint of exactly the right size a small ring may be made temporarily adequate by cutting through the oval ring just in front of the attachment of the external bar so increasing its diameter by leaving a gap at this point (Fig 548) Similarly a splint in which the ring is too large may also be used temporarily by placing a large pad between the outer portion of the oval and the outer aspect of the thigh thereby pulling the inner portion of the ring to its normal site under the ischial tuberosity (Fig 549) Such alterations of unsuitable splints must only be regarded as temporary measures to be used until the correctly fitting splint is obtained and such splints should not be employed any longer than is absolutely necessary

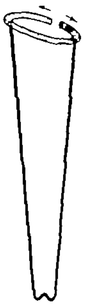

FIG 548

Circumference of ring increased by cutting through anterior part of oval bar and opening out a gap.

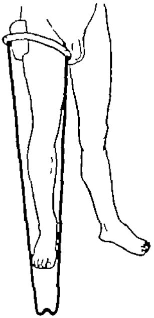

FIG 549

Use of pad with a splint which has too large a ring: pulling the ring into its normal position under the ischial tuberosity

Probably the most common objection to the use of the Thomas splint concerns the difficulty of preventing sores on the buttock and the inner side of the groin over the adductor muscles Thomas himself realized that in very fat people in whom the flesh of the buttock tended to bulge over all sides of the ring care was needed if skin troubles were to be avoided and he suggested that for such people the padding on the ring should not consist of more than two layers of felt together with the covering leather sheath Sores in this type of patient or in fact in any patient cannot be avoided by increasing the thickness of the ring but rather by constant attention to the skin and prevention of dampness which is the invariable precursor of sore formation In using the Thomas splint the nurse must be instructed to attend to the skin in the region of the ring at least every two hours during the first few days after its application The skin under the splint is gently moved so that a new point of pressure becomes available between the ring and the ischial tuberosity while at the same time the whole area is massaged with a minimum amount of surgical spirit which dries and hardens the skin before the application of a thin layer of dusting powder This process is repeated constantly the interval which is about two hours being extended later to three and four hours but under no circumstances must the skin of the buttock and groin be left for long without attention. The use of a small amount of surgical spirit in this way is of the very greatest advantage but the use of excessive quantities and especially the failure to dry off all excess spirit predisposes to sore formation.

period of two to three weeks, and naturally will not occur if the fixation is constantly interfered with and the splint is frequently removed for inspection of the limb

ACCESSORIES TO THE USE OF THE THOMAS' SPLINT

As a rule no fixed foot-piece is necessary or even desirable a foot-piece fixed to the splint is often employed with the object of preventing contraction of the calf muscles and the development of an equinus deformity of the foot, but its use has several disadvantages, the chief of which is the provision of a fixed point of pressure against which the patient can obtain leverage, thus minimizing the complete rest at the site of fracture which is the essential feature of fracture treatment If the foot is exercised freely each day deformity is usually avoided, especially if the extension straps have been correctly applied, their attachment to the skin ceasing at a point at least 2 in above the base of the malleoli The ankle-joint is thus left free and unhampered for movements which the patient must practise daily These voluntary exercises should be implemented by daily passive stretching of the calf muscles, the movement being performed while the limb is steadied by holding the ankle firmly with the other hand

1 **Balkan beam**—Although not in any sense essential to the use of the Thomas' splint, the Balkan beam with its counterweights can make the handling of the patient much easier as regards nursing and skin attention The patient can raise his buttock from the bed much more easily, enabling the nurse to attend to the skin of the buttocks and hips, an advantage which justifies the use of the beam, especially where the standard of nursing is not of the highest

2 **Foot rest to raise the splint from the bed**—This addition to the splint is useful, preventing as it does any possibility of pressure of the back of the heel on the bed, and allowing freedom of all movements of the foot

GENERAL CONSIDERATIONS

It is often stated that the Thomas' splint is extremely difficult to manage, and that sore formation in the groin, on the buttock, and occasionally in the region of the anterior superior spine of the ilium are the inevitable sequelæ of its employment Other objections have been raised to the interference of the ring of the splint with the normal bodily functions, and it has been suggested that the use of the bed-pan and the urine bottle are matters of extreme difficulty These criticisms are entirely unjustified, as all these so-called disadvantages arise from the surgeon's failure to use the splint in the manner prescribed

In the first instance, careful measurements of the exact size of the ring necessary for the particular patient is an essential step If the circumference of the ring is too small it will not pass up to its normal point of support on the ischial tuberosity, and by its tight grip on the thigh must interfere with the circulation of the limb On the other hand, if the ring is too large its pressure on the tuberosity is lost, and the ring slides upwards over the tuberosity and inwards to the middle line, mechanically interfering with the

anus and often with the urethra and at times even taking pressure on the anterior superior spine of the ilium.

If it is impossible to obtain a Thomas splint of exactly the right size a small ring may be made temporarily adequate by cutting through the oval ring just in front of the attachment of the external bar so increasing its diameter by leaving a gap at this point (Fig 548) Similarly a splint in which the ring is too large may also be used temporarily by placing a large pad between the outer portion of the oval and the outer aspect of the thigh thereby pulling the inner portion of the ring to its normal site under the ischial tuberosity (Fig 549) Such alterations of unsuitable splints must only be regarded as temporary measures to be used until the correctly fitting splint is obtained and such splints should not be employed any longer than is absolutely necessary

Fig 548

Circumference of ring increased by cutting through anterior part of oval bar and opening out a gap.

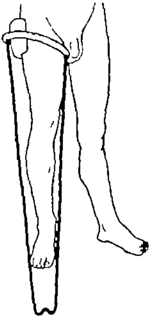

Fig 549

Use of pad with a splint which has too large a ring: pulling the ring into its normal position under the ischial tuberosity

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The advantages of the Thomas' splint must always outweigh its disadvantages It provides an easy method whereby it is possible to immobilize the lower limb completely, to treat efficiently and easily fractures of the femur, surgical conditions of the knee-joint, and in many instances fractures of the upper portion of the tibia and fibula

1 **Restoration of alignment**—In no other method of treatment of fractures of the femur is it possible to restore the alignment of the bone so effectively and at the same time observe the correction during the whole course of treatment When a genu valgum or genu varum deformity is present the alteration of the alignment of the limb is evident when the knee is extended, but all trace of the deformity may disappear if the knee is bent to right angles Similarly, if a fracture of the femur is treated with the knee in the flexed position it is impossible to be certain that the limb will be straight when the fully extended weight-bearing position is assumed As the treatment in the Thomas' splint is carried out with the limb practically in full extension, errors in the weight-bearing alignment are avoided Similarly, with a correctly applied posterior splint the normal anterior curve of the femur is preserved, and the normal line of action of the thigh muscles and the knee-joint are maintained without difficulty

2 **Full length**—Although it has often been asserted that full length following a fractured femur in a healthy adult man cannot be obtained by the use of fixed extension, the records of those hospitals and clinics in which the method is practised prove the contrary Not only can full length be obtained, but during the whole course of treatment the length of the broken limb can be measured and compared with its fellow, thus preventing the unnecessary overextension and possible non-union of the bone which, in some instances, have resulted from the excessive use of weight traction When full length has been obtained no further extension of the limb is necessary or advisable, fixation alone is required to complete the consolidation of the fracture and to promote bony union without excessive callus formation

3 **Transport**—On this point the treatment of an injury of the thigh by Thomas' method is not open to any criticism Transport of the patient, even over long distances, is simple and safe, the bone is maintained in position without risk, and, if for no other reason, the use of the Thomas' splint in the treatment of fractures of the femur is ideal in war surgery

The official figures of the results of compound fractures of the femur in the 1914-18 war are indeed startling Before the general use of the Thomas' splint in the forward dressing stations the death-rate from compound fracture of the femur reached the appalling total of 80 per cent, whilst after its general application the fatal results formed only 20 per cent of the total These official figures are of themselves the strongest advocates for its universal adoption, and in this connection the words of Thomas, which I have previously quoted, seem to be particularly apt

CHAPTER LVII

THE USE OF THOMAS' FRAMES

AT the commencement of the 1914-18 war plaster of Paris fixation was as popular as it is to-day but the complications which arose from its indiscriminate use led Sir Robert Jones Inspector of Military Orthopædics to make the following statement I would urge my young colleagues at the front to discard it altogether In war time cases pass from surgeon to surgeon at short intervals If in the light of modern advances fixation of wounds about the hip is contemplated by means of plaster it is often better to postpone its application until the patient reaches his final or semi final destination The removal and reapplication of an extensive hip plaster is by no means a minor procedure

The well known methods of immobilization by means of the Thomas double frame and abduction frame will be described in some detail In the case of injury about the hip spine and buttock they will be found safe and efficient In their application some little practice and experience is required and inexperienced nurses need some elementary tuition

THE THOMAS' DOUBLE FRAME

This frame (Fig 330) is supplied by any instrument maker One frame will fit many patients but for the first case the following measurements are required —

1 Length from axilla to external malleolus
2 From axilla to gluteal fold
3 Circumference of the chest at level of nipples

FIG. 330
Thomas double frame
(After Sir Robert Jones)

Application—To apply the frame the patient is raised gently by three or four assistants and the appliance passed under him from feet to head The buttocks rest on either side of the horse-shoe shaped gap in the back pad designed for nursing purposes The wings of the splint are pliable and should be moulded closely round the patient s body especially at the back The moulding should be accurate to prevent side movements A thick pad of wool is placed under each knee so that the leg may lie in slight flexion These pads should never be omitted otherwise genu recurvatum may result The two small crutches which grip the ankles should also be well padded Finally in the case of the simple double frame the knees are bandaged firmly to the posterior bars and the toes protected from the weight of the bedclothes by an improvised cradle

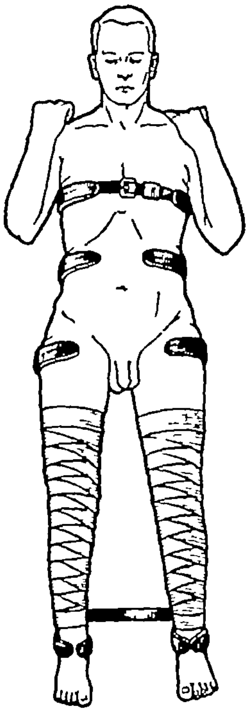

Fig 551
Thomas' double frame applied
(*After Sir Robert Jones*)

The frame is made intentionally without foot pieces, in order to prevent the patient exerting pressure which might be transmitted to the hip or spine A light plaster of Paris bandage or sandbags suitably arranged will counteract foot-drop

If the frame is too short, the deficiency below can be made good by the application of posterior gutter knee splints If it is too long, the back pad will require readjustment on the framework so that the gap will be in the proper position for nursing purposes For the too long frames the pads under the knees will require to be larger and the heels will need protection by plaster of Paris or other means, as they will lie on the leg bars of the splint instead of below the ankle crutches

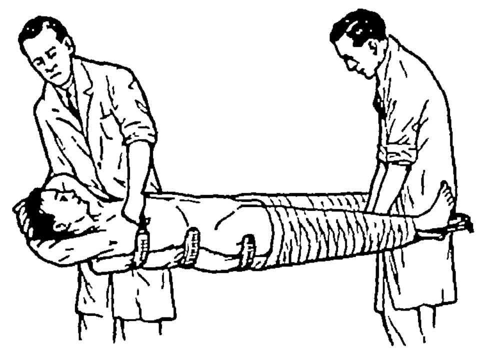

Fig 552
Patient in a Thomas' double frame being transported

Fig 551 shows the frame applied, Fig 552 how admirably the splint is adapted for transport purposes It acts in fact as a permanent form of stretcher

THE ABDUCTION FRAME

This is a modification of the Thomas' double frame Extension in addition to fixation and abduction is secured and easily maintained As in the case of the double frame, both limbs are fixed Skin extension is provided by strapping, and counter-extension by a smooth, well-padded leather groin strap The latter is applied on the side opposite to the injury The abduction frame as originally made was difficult for transport On boats, trains and ships the abducted limb was a hindrance The splint was therefore modified by supplying a hinge (Fig 553) which permits the limbs to be placed parallel during transport When the patient arrives in hospital the abducted position is restored without difficulty Patients treated on abduction frames may be lifted and moved without pain and without disturbing the extension Dressings can be changed without interfering with fixation If the wound involves the buttocks, the splint

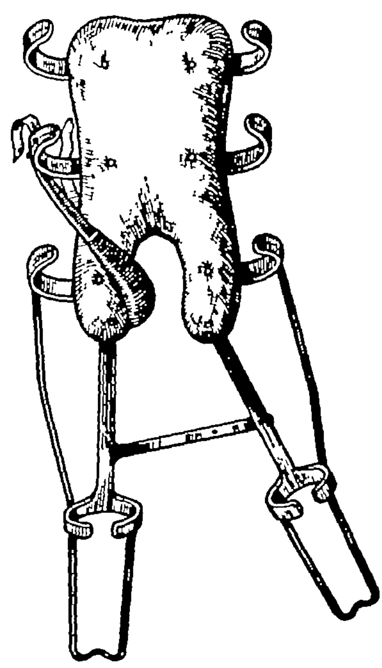

Fig 553
Hinged left abduction frame
(*After Sir Robert Jones*)

should be modified by the removal of a portion of the back part of the pad and the framework altered so that the wound escapes pressure (Fig 554)

Many difficulties encountered by the writer have been surmounted by the use of this frame and he can commend it with confidence to others who are not already familiar with its efficiency The measurements mentioned already for the manufacture of the Thomas double frame are the same measurements required by the instrument maker for the abduction frame but it must be stated whether it is for the right or the left limb

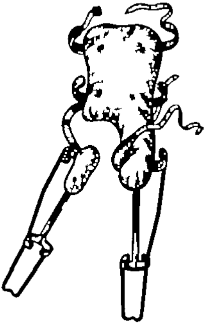

FIG 554

Modified abduction frame for pelvic wound. To be replaced by complete frame as early as possible.

Application—Apply adhesive strapping with terminal loops to both sides of both legs as described on p 618 The next step is to apply the groin strap along the gluteal fold of the sound limb carrying it round the groin to the buttons provided for the purpose on the splint wing Next apply traction to the injured limb by tying the tapes attached to the plaster strapping to the notch on the end of the splint (Fig 555) Slight traction is applied to the uninjured limb in a similar manner This prevents tilting of the pelvis Finally the knees with large pads behind to produce slight flexion are bandaged securely to the posterior bars as previously described If the frame is at hand and the strapping and bandage in readiness the whole application does not take more than ten minutes

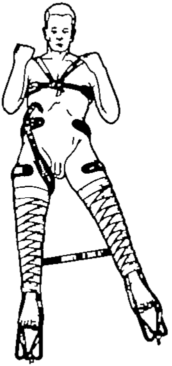

FIG 555

Left abduction frame applied.
(*After Sir Robert Jones*)

As in the case of the Thomas double frame a long or short patient can be equally accommodated by intelligent adjustments The writer has made use of these frames for many years and continues to employ them as a routine in preference to plaster fixation As mentioned already the judgment of the individual surgeon must be the last word but in war when no two cases are alike it is well for every surgeon to have at least two strings to his bow

To those unaccustomed to the use of the frames just described certain minor difficulties may arise In the first place they must make sure that they are properly constructed *i.e* the two vertical bars must not be too far apart and the gap left in the pad for sanitary purposes must not be too wide Such faulty frames allow the pelvis to slip back between the bars and the alignment of the injured limb becomes distorted The back pad or saddle is tied by tapes

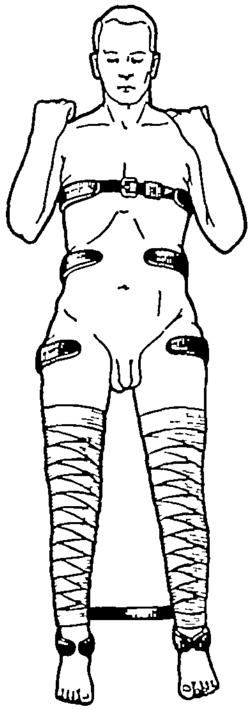

Fig 551
Thomas' double frame applied
(*After Sir Robert Jones*)

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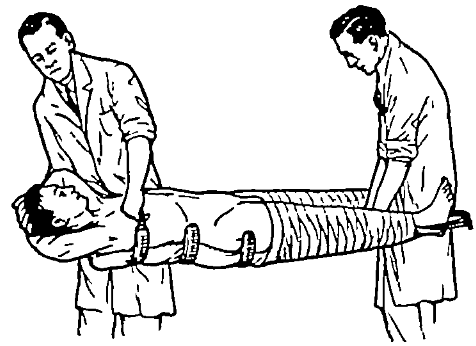

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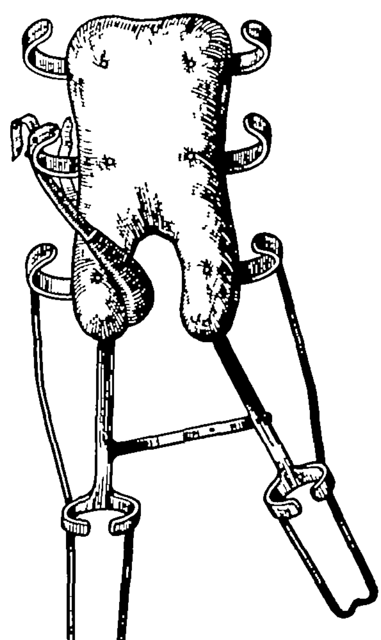

Fig 553
Hinged left abduction frame
(*After Sir Robert Jones*)

CHAPTER LVIII

THE USE OF BRAUN'S SPLINT AND ITS MODIFICATIONS

BRAUN'S splint for the lower limb has the great merits of simplicity and standardization One size fits almost any adult and does equally well for the right and left sides The splint was popularized by Böhler who added pulleys to the simple frame designed by Braun in 1916 Böhler without destroying the simplicity of Braun s splint adapted it for use in fractures of both the thigh and the leg

Since that time many modifications and additions have been described The splint is much used in Britain particularly for fractures below the knee and there are two principal forms —

(a) The simple frame illustrated in Fig 556 for injuries below the knee and

(b) The Braun s splint with three or more pulleys, used for treating fractures of the femur Flemming s modification is more comfortable because the movable lateral prolongation avoids pressure on the perineum (Fig 557 *a* *b* and *c*)

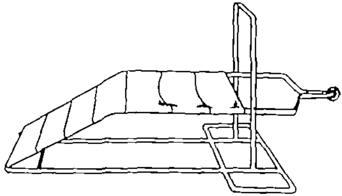

Fig 556

Braun s splint. This is the one-pulley model used for treating fractures of the tibia and fibula. Note how the bandage is tight under the thigh but allows room for the calf muscles.

Other useful modifications are Fitzgerald s adjustable splint which permits variable flexion of the distal fragment of a fractured femur and Farquharson s simplified wooden model The small additions such as those illustrated in Fig 557 *d* and *e*, though occasionally useful are not often necessary

Braun s splint compares favourably with Thomas splint in the treatment of fractures of the lower limb although it is probably true that fixation of a fractured femur is more complete with a well fitting Thomas splint when it is applied by a surgeon who has had special training in its use

Skeletal traction—Providing the surgeon remembers that non union may be caused by overextension skeletal traction is preferable to plaster

to the frame It should be packed tightly and evenly with lambs' wool so that the metalwork cannot be felt through it

Nursing—The nursing is an important matter The groin strap exerts pressure on the ischial tuberosity of the sound side, but the skin becomes hardened and the patient gets used to this pressure after the first couple of days During this period the groin strap may be removed for five minutes every four hours to enable the skin to be rubbed with spirit and powdered The strap is secured again in the same hole as before, but as much as possible over a different skin surface After the third day attention once or twice in the twenty-four hours is usually sufficient The nurse must be warned that any attempt at padding with wool is futile, it hastens the formation of a sore and interferes with extension By placing a box under the transverse bar between the ankles the frame is raised sufficiently for washing of the buttocks and for nursing purposes The patient is never taken from the splint, and loosening of the bandages or groin strap must be forbidden

I have obtained some information from a sister working for an eminent orthopædic surgeon in a hospital where the frame is now in constant use She described how to make the bed of a frame patient once a week The bedclothes are removed, leaving a blanket covering the patient The patient, firmly bandaged on the frame, is lifted on to a trolley by at least four people, the mattress is turned top to bottom so that any blocks or boxes which were used to raise or support the frame would rest on a fresh portion A clean bottom sheet is put on the bed The draw-mackintosh and draw-sheet are folded to about 14 in wide and the patient is lifted back In attending to pressure parts in the case of injury to the hip the frame may be tilted laterally a few inches off the bed, first on one side and then on the other The patient is rolled slightly over and supported by an assistant on the opposite side This manœuvre allows the hand of the nurse to reach every part of the back It disturbs the patient least if one side of the back is done first and then the other The buttocks, sacrum and lower portion of the back can be reached easily by raising the transverse bar as mentioned above

It facilitates nursing, especially if there are posterior wounds, if the frame is kept permanently raised from the bed by three blocks of wood placed transversely equidistant across the mattress These blocks are 36 in long by $8\frac{3}{4}$ in high They are not essential, and if they are used a number of bolsters and pillows are required to support the head A little practice is worth pages of description If the skin becomes red and pressure sores threaten under the groin strap, the frame should be fastened to the raised foot of the bed, so that the patient's body-weight adds to the traction and relieves the pressure on the strap

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plaster extension strapping) Morison's tubular gas pipe frame (Fig 558) is the best form of Balkan beam and can also be used for attaching an *overhead hand grip*

THE SPAIN WEIGHT HANGER AND WEIGHTS

Mr A. W Spain, Clerk of Works, Royal Northern Hospital, has kindly supplied the following details of construction (Fig 559).

Materials required for each complete unit—Twenty-six inches of ¼ in diameter round mild steel for hanger frame; 3-in. diameter × ¼-in. thick mild steel disc for weight pan quantity of old lead piping and scrap for casting weights.

Method of manufacture—A line is struck across middle of 3-in. disc. A $\frac{3}{16}$-in. hole is then drilled at ½ in centre in from each outside The holes are countersunk on the underside

The two ends of 26-in. × ¼-in. mild steel rod is filed to a reduced diameter of $\frac{3}{16}$ in. to a distance of ¼ in. in from each end, thus forming a shoulder The middle of this rod is then heated and the rod pulled together around a piece of ⅞ in. diameter steel rod. This in turn is clamped in a vice and both side pieces pulled around to right angles. The ⅞ in. mandril piece is then removed and the shaped part inserted in the jaw of the vice and gripped tight. The two side pieces are now pulled over to an angle of 90° to their previous position; this will bring them 2 in. apart Remove from vice and cool

The two reduced ends are inserted through holes in disc piece and the projecting portion riveted over the countersinking

The weights (Fig 559) are cast by melting down any old scrap lead and pouring into a mould marked off in thicknesses to give various size weights.

A short piece of old 3-in. pipe will make an admirable mould and the weights will come out quite easily if the inside is smeared with chalk.

A ½-lb. weight is approximately [illegible] in. thick finished size
A 1 lb. " " ⅜ " " " "
A 2 lb. " " ¾ " " " "
A 3-lb " " 1⅛ " " " "

If the weights are cast a little full they are much enhanced in appearance by turning a skimming off each face to bring them down to the correct weight.

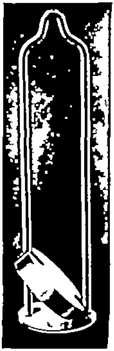

FIG 559
Spain's Weight Hanger and Weight.

PREPARING THE SPLINT

The mechanics of the splint and the comfort of the patient depend on the splint being prepared properly and it is wise to have a standard method of doing it A 6-in flannel bandage is passed tightly between the thigh bars of the splint (*Fig 557*) *and even more tightly over the angle where the knee* joint will rest The bandage then becomes looser to allow for the calf muscles but is again tight at the lower end of the splint where the tendo Achillis will lie on it The bandage is held in place temporarily with 4-in paper clips until a stitch of cotton has been run along the inner side of each bar holding the bandage firmly when the paper clips are removed The thigh should rest on the splint but the slings of bandage allow room for the calf muscles The aim is to keep the tibia parallel to the bars of the splint and in the same horizontal plane

APPLYING THE SPLINT

This is quite easy if all the necessary equipment is at hand We will assume that fracture boards are in place and the bandaged splint is lying on the floor by the bedside The first step is to adjust the box for the sound foot This box is placed at the foot of the bed where it rests

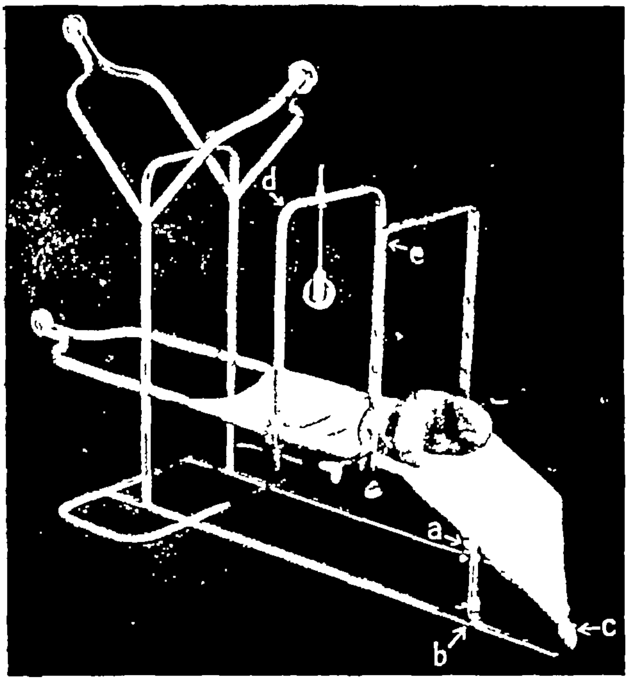

Fig 557
Braun's splint modified by Flemming *a*, *b*, *c* may be fixed to either side of splint, which is here arranged for left limb, *d* and *e* are removable additions useful for treating certain fractures of the tibia
(*Royal Northern Operative Surgery*)

strapping Heavy traction can be used safely during the first few days when reduction is easiest, but a weight over 8 lbs becomes dangerous after a week unless a radiograph shows necessity for it

EQUIPMENT NECESSARY FOR USE WITH BRAUN'S SPLINT

Detail is most important in using this splint, and the following equipment should be at hand (Fig 558) Fracture boards, 6-in flannel bandages, needle and thread, one dozen 4-in paper clips, a ball of strong blind-cord (No 5 is a good size), weights, 10-in bed-blocks, back-rest, a closed wooden box (25 × 30 × 40 cm) for the sound foot, an overhead hand grip for the patient to lift himself by the arms and plaster-strapping for the sole of the foot (3-in flexible adhesive

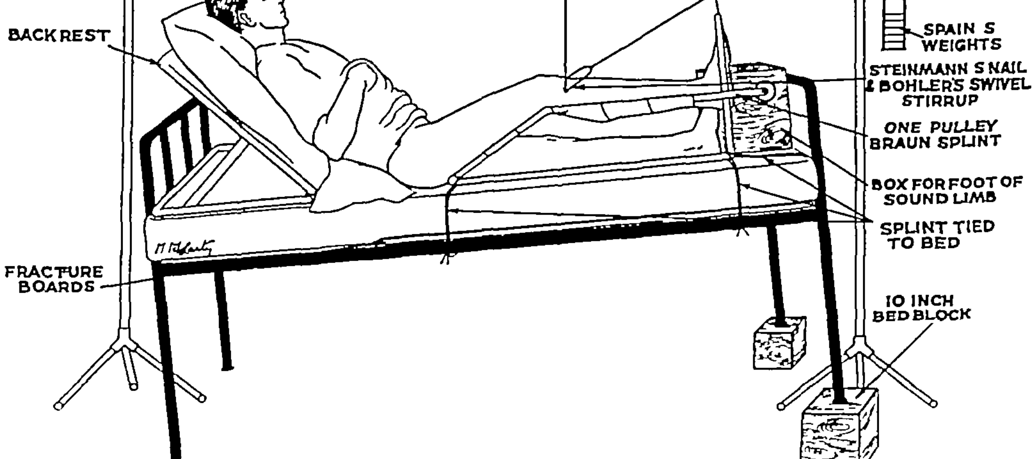

Fig 558
The treatment of a fractured femur on a Braun's one-pulley splint by skeletal traction from the tibial tuberosity Morison's frame is being used

plaster extension strapping) Morison's tubular gas pipe frame (Fig 558) is the best form of Balkan beam and can also be used for attaching an overhead hand grip

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Method of manufacture—A line is struck across middle of 3-in disc. A $\frac{3}{16}$ in. hole is then drilled at ⅝ in centre in from each outside The holes are countersunk on the underside

The two ends of 30-in. × ¼ in. mild steel rod is filed to a reduced diameter of $\frac{3}{16}$ in. to a distance of ¼ in. in from each end, thus forming a shoulder The middle of this rod is then heated and the rod pulled together around a piece of ¾ in. diameter steel rod. This in turn is clamped in a vice and both side pieces pulled around to right angles. The ¾ in. mandril piece is then removed and the shaped part inserted in the jaw of the vice and gripped tight. The two side pieces are now pulled over to an angle of 90 to their previous position; this will bring them 2 in. apart. Remove from vice and cool.

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APPLYING THE SPLINT

This is quite easy if all the necessary equipment is at hand We will assume that fracture boards are in place and the bandaged splint is lying on the floor by the bedside The first step is to adjust the box for the sound foot This box is placed at the foot of the bed where it rests

firmly against the bed-rail or, if necessary, it is secured by a screwed-on wooden extension The patient is moved so that the sole of the uninjured limb presses against the box when the knee is straight The patient then sits up and the back-rest is put in position with enough pillows to allow him to rest comfortably with the knee of the sound limb quite straight The injured leg is now lifted from the bed, and the splint slipped under it so that the flexed knee lies exactly at the angle of the splint, which is then secured firmly to the bed with blind-cord so that it cannot move up, down or sideways It is a good plan to mark with a skin pencil the level of the knee-joint on the inner and outer side of both knee and splint, so that the patient can himself correct slight alterations by seeing that the four marks are always in line Plaster-strapping or skeletal traction is now applied, the foot of the bed raised on blocks, and the patient instructed how to lift himself in bed by using the overhead hand grip

AFTER-CARE

The patient is encouraged to move his foot and toes frequently and to keep his knee at the proper level in the splint by using the marks already described The foot should be steadied by a weight of 3 or 4 lbs , fixed by plaster-strapping to the sole This helps to stabilize the fracture and prevents foot-drop, though it is not necessary when traction is taken from the heel If rotation occurs it can be controlled by vertical traction through a cord attached to the inner or outer end of the stirrup (Fig 558) Opinion is divided on the ease of nursing these patients, but on the whole there are fewer difficulties with a Braun's than with a Thomas' splint

When the fracture has united and is approaching consolidation, skeletal traction is removed and, in necessary cases, plaster-strapping is substituted Separate strapping extensions are stuck to the thigh and leg, and fixed to wooden spreaders from which blind-cord passes over two of the pulleys on the splint Three-inch flexible adhesive plaster extension bandage is suitable, and about 5 lbs weight on each cord is usually enough for fractures of the femur at this late stage This change allows movement of the knee in the following way The weight is removed from the lower extension and Böhler's knee-flexing apparatus (Fig 560) is slipped under the limb, which remains on the splint from which the flannel bandages have been cut away below the knee they are replaced later and then held in position by 4-in paper clips The bar of the apparatus is put on the lowest notches, and the patient is encouraged to relax the quadriceps until the heel touches the bed He then attempts active extension. This exercise is repeated several times a day and it is surprising how soon it is possible to flex and extend the knee without pain, even when the bar is placed in the highest notches and the knee moves through a right angle It is then usually time to take away the extension and to allow the patient to lift the limb from the splint, swing himself sideways across the bed and

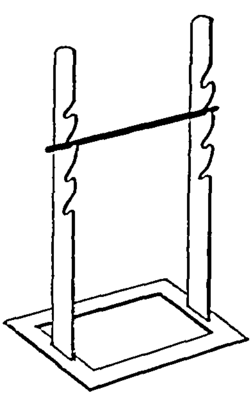

Fig 560
Böhler's knee-flexing apparatus Height, 19 in

continue the movements with his thighs supported by the mattress This routine is advisable for patients recovering from fractures of the femur For injuries below the knee the plaster strapping stage can be omitted and the knee flexed over the apparatus with the limb on the splint as soon as the Steinmann's nail has been removed

Sitting in a chair is the next stage and subsequent steps depend on circumstances and allow a choice of crutches a walking chair sticks plaster of Paris or an elastic adhesive bandage Massage is not usually necessary but occasionally in elderly patients it is worth while giving radiant heat or diathermy to help to regain movements of the knee and ankle

BRAUN'S SPLINT IN SPECIAL CASES

Fractures of the shaft of the tibia can be treated very satisfactorily on a one-pulley Böhler Braun's splint (see Fig 556) There are two ways of doing it —

(*a*) By IMMEDIATE REDUCTION using Böhler's screw traction apparatus The patient is anæsthetized and a Steinmann's nail driven through the

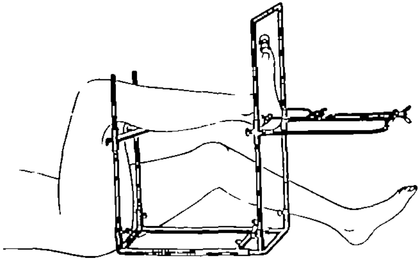

FIG 561
Böhler's screw traction apparatus. (*Down Bros*)

os calcis (p 620) The screw traction apparatus is fixed to a Böhler's stirrup in the way shown in Fig 561 Traction is applied and the fragments are manipulated into position While still upon the screw traction apparatus the tibia is radiographed in two planes

When the alignment is satisfactory a piece of felt 3 in wide is stitched around the top of the leg below the knee and a posterior plaster slab is placed from this around the back of the heel as far as the tips of the toes A second slab is placed as follows it passes from the felt down the lateral aspect of the leg across the heel and up the medial aspect of the leg In order to accommodate the Steinmann's nail the plaster is cut through half its width with a scalpel Six inch gauze bandages hold the slabs in position and the cast is completed by 6-in plaster bandages The gauze bandage

has the additional advantage of allowing for the probability of post-operative swelling The plastered limb is then placed upon the Braun's splint and a 4 to 5 lbs weight suspended from the stirrup, which is usually left in place for three or four days and then removed It is advisable to leave the Steinmann's nail in position in case it is needed for further traction when the plaster is changed or extended above the knee

(*b*) BY GRADUAL EXTENSION—A Steinmann's nail is driven through the os calcis and the limb placed on a one-pulley Braun's splint The stirrup is attached to the nail and a weight of about 8 lbs is suspended from it The weight is increased until radiographs show good reduction, but the earlier warning against overextension must be remembered The limb should be left on the splint until there is some union, when a walking plaster can be substituted If X-rays show that the fracture is in good position in the walking plaster, then the stirrup and nail are removed

Fractures near the ankle-joint—As a rule these fractures are treated best by immediate reduction and plaster of Paris, but there are rare occasions on which one of the two methods just described may be useful and this is particularly true of fractures which come under treatment late or in which a posterior malleolar fragment has proved intractable

Fractures of the tarsus and metatarsus—These fractures are also generally treated in plaster of Paris Much swelling often accompanies them and this is reduced by placing the plastered limb on a Braun's splint Böhler's method of treating fractures of the os calcis is well known, and here again at the close of the operation Braun's splint may be used for the plastered limb

Fractures of the femur—FRACTURES OF THE NECK are divided into medial and lateral types

Medial fractures are subdivided into abduction and adduction, depending on the angle between the head and neck of the bone *Abduction* fractures are almost always impacted, and neither operation nor splint is necessary *Adduction* fractures, on the other hand, are notorious for their unwillingness to unite and are treated by Smith-Petersen's nail Traction on a Braun's splint is advisable (*a*) as a preliminary to operation, (*b*) when the general condition forbids nailing Traction is best obtained by a Steinmann's nail driven through the tuberosity of the tibia (p 620), and although 10 lbs is usually sufficient to obtain reduction, double this weight should be used if radiography shows failure of reduction after three days There is no need to abduct the limb widely, because the weight tilts the pelvis and this gives enough abduction for these fractures

Lateral fractures used to be called extra-capsular and should not be treated by nailing but by skeletal traction from the tuberosity of the tibia on a Braun's splint An extension of 10 lbs for ten weeks is a good working rule and union is almost invariable after that time Plaster-strapping extension is then substituted to regain flexion of the knee Sitting in a chair and partial weight-bearing with crutches soon follow, and rapid progress towards full weight-bearing is usually quite safe

FRACTURES OF THE UPPER THIRD are often difficult to treat because of the flexion and abduction of the proximal fragment Many surgeons prefer to use a Jones' abduction frame, but Braun's splint can be employed, in which case a Balkan frame and wide abduction of both limbs are generally necessary Skeletal traction of 20 or 30 lbs from the tuberosity of the tibia may be required to obtain reduction Fitzgerald's modification of Braun's splint permits variable flexion of the distal fragment and may

prove useful in these fractures As a rule extension is necessary for at least three months although the weight may be decreased after reduction of the fracture Plaster strapping extension may be substituted as already described (p 638) as soon as union has occurred but consolidation is not

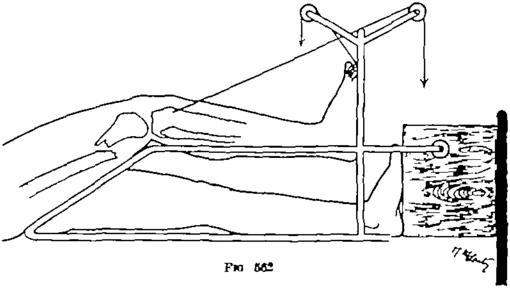

Fig 562

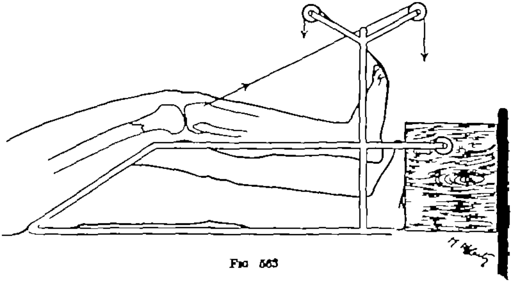

Fig 563

Supracondylar fracture of the femur treated on a Braun's splint by skeletal traction from the tuberosity of the tibia. In the upper diagram the limb lies on the splint in the usual position but angulation of the fragments persists. The lower diagram shows how the fragments can be correctly aligned by moving the limb down the splint so that the angle of the splint is behind the fracture instead of behind the knee joint. (*After Böhler*)

complete Böhler's knee flexing apparatus is then useful and radiant heat to the knee is advisable in elderly patients

Fractures of the middle third are also treated by skeletal traction from the tuberosity of the tibia with weights even up to 30 lbs for the first week (see Fig 538) It is of great importance to regain the normal

anterior convexity of the bone and this can be achieved either by an overhead sling of flannel bandage at the site of the fracture or by a small pillow beneath it Fitzgerald's new removable brackets attempt this by making the proximal half of a Braun's splint convex instead of flat Non-union is a serious complication in fractured middle third of the femur, and it is better to be satisfied with a moderate anatomical position which will give a good functional result rather than to persist for a long time with heavy weights which may cause non-union Three months' extension is usually necessary and the change to plaster-strapping extension (p 638) depends upon both clinical and radiological evidence Refracture occasionally occurs and is such a disappointment to all concerned that a weight-bearing caliper splint for a few months is sometimes a wise precaution when walking begins

FRACTURES OF THE LOWER THIRD—Skeletal traction from the tuberosity of the tibia is again appropriate, and the special difficulty is that the lower fragment is usually displaced backwards and makes an angle open forwards This can sometimes be corrected by arranging the Braun's splint so that its angle lies under the fracture instead of under the knee-joint (Figs 562 and 563) Some fractures of the femoral condyle are better treated in plaster

Braun's splint for compound fractures—When the closed plaster method is to be used it may be combined advantageously with a Braun's splint Braun's splint provides the necessary elevation for a lower limb in plaster, but when the splint is to be used the plaster must be applied with the knee and, when necessary, the hip both flexed at about 30° Alternatively, compound fractures can be treated by a Braun's splint with the aid of skeletal traction, a method which has much to recommend it when there is a possibility of gas gangrene developing Plaster can always be applied later when this danger has passed

Braun's splint in lesions of the soft tissues—Braun's splint is useful for fixation and elevation of the lower limb Soft tissue injuries, especially those below the knee, thrombosis, phlebitis, cellulitis, erysipelas and gangrene are all conditions which, in suitable cases, benefit from this splint

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CHAPTER LIX

THE USE OF CRAMER WIRE

CRAMER wire consists of two stout straight parallel wires connected together by thinner curved wires arranged at intervals of half an inch from each other (Fig 564)

Advantages—The wire can be bent manually It is strong enough when bent and bandaged to a limb to give firm support It is light and its uses are numerous

Padding—The wire is padded by placing sufficient wool along its concave surface to make it convex when bandaged into position The wire is kept in stock padded

Method of padding—A piece of wool is cut from an ordinary wool roll This piece is 6 in longer than the length of Cramer wire to be padded (Fig 565) It is folded on itself like a jam roll consisting of three thicknesses of wool (Fig 566 inset) The long ends are turned over the cut edges of the wire (Fig 566) and bandaged firmly into position (Fig 567)

Fig 564—The strong longitudinal pieces are joined transversely by narrow gauge wires

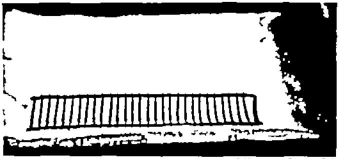


Fig 565—The width of the wool for padding is the width of the wool roll. In length it extends 3 in. beyond each end of the Cramer wire

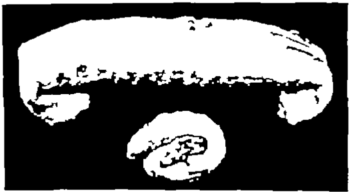


Fig 566—The wool overlap protects the rough wire ends. Inset shows the large convexity formed by the "jam" roll of wool.

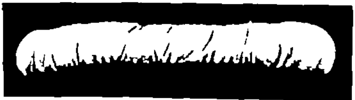


Fig 567—The padded wire.

FRACTURES

As a first aid measure in the treatment of fractures Cramer wire is very useful Its use in fracture work proper is limited The following description therefore refers mostly to immediate measures for immobilizing a broken bone

Fracture of humerus—This fracture is immobilized by bandaging firmly to the upper arm a U-shaped strip of wire

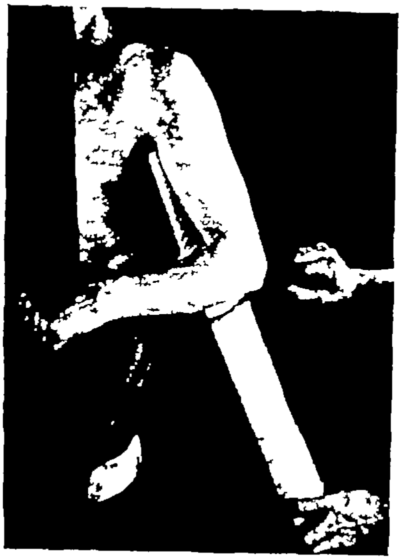


FIG 568—The length from axilla to elbow is marked off

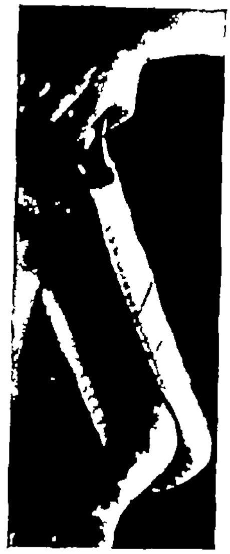


FIG 571—The shaped arm splint is in position It is being cut at the shoulder level

FIG 569 Bending the wire

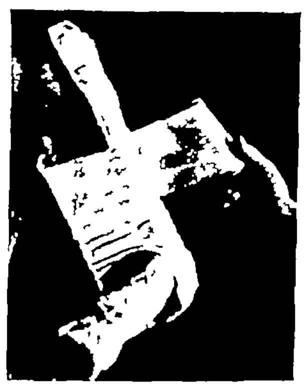


FIG 572—Fixing the splint in position

FIG 570—Marking the 3-in gap for elbow room

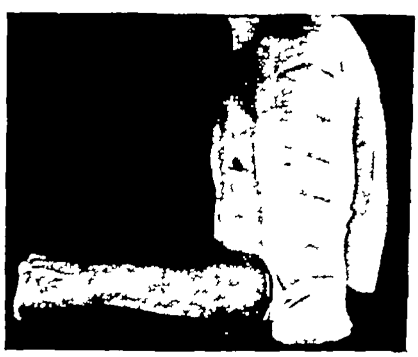


FIG 573—The completed fixation A sling is provided

METHOD—A padded length of wire is placed along the inner surface of the sound arm A pencil mark is made at the level of the elbow (Fig 568) At the level of the pencil mark the wire is bent manually to a right angle (Fig 569) Three inches from the first mark a second pencil line is drawn (Fig 570) At the second mark the wire is bent again to form a U In this form it is fitted to the upper arm and the excess length on the outer aspect cut off with wire cutters or pliers (Fig 571) The splint is then bandaged firmly to the limb (Fig 572) Owing to the depth of padding the splint protrudes below the elbow level This protrusion is bandaged by the figure-of-eight method and prevents the splint from slipping (Fig 573) A sling is provided

Fractures of the elbow—Fractures in this region are best treated by a strip of padded wire bent round the elbow

METHOD—The measured length of wire is bent to a right angle (Fig 569) at the elbow level In most of these fractures the forearm falls into the

prone position To avoid supinating it forcibly and possibly causing further damage at the elbow the wire along the forearm is twisted on itself into the mid prone position (Fig 574) The splint is then placed along the posterior aspect of the arm and the dorsal aspect of the semi prone forearm (Fig 575) A layer of wool is placed on the front of the limb

Fig. 574—Pronating the wire.

Fig 575—The splint and arm in position

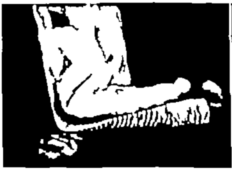


Fig 576—The wool layer and pad are in place.

Fig 577—The splint and wool are bandaged in position.

A small wool pad separates index finger and thumb (Fig 576) The splint is then fixed to the limb by a firmly applied bandage (Fig 577) A sling is provided to support the limb

Forearm fractures—Two Cramer wire splints are necessary

METHOD—One padded length of wire is bent to 90 It is fitted along the back of the arm and forearm A shorter splint is laid along the front of the

Fig 578—The splints, wool and arm in position.

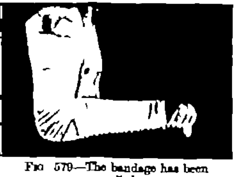


Fig 579—The bandage has been applied.

For clearness the forearm is shown supinated. This position is only allowable for fractures of the upper third of the radius.

forearm extending from elbow to wrist. A small wool pad separates finger and thumb A layer of wool is placed along the front of the arm (Fig 578) The splint and wool are held firmly in position by a bandage (Fig 579)

Wrist fractures—A single short strip of Cramer wire is used

METHOD—The splint is placed on the back of the forearm It extends from knuckles to elbow (Fig 580) A wool pad separates the finger and thumb and a layer of wool is placed along the front of the forearm Splint and wool are fixed by a firmly applied bandage (Fig 581) Full movement of the elbow and fingers is allowed (Fig 582)

FIG 580—The splint extends from the elbow to the knuckles

Metacarpal and finger fractures—Drop wrist—A single piece of Cramer wire is needed

FIG 581—The bandage is applied firmly

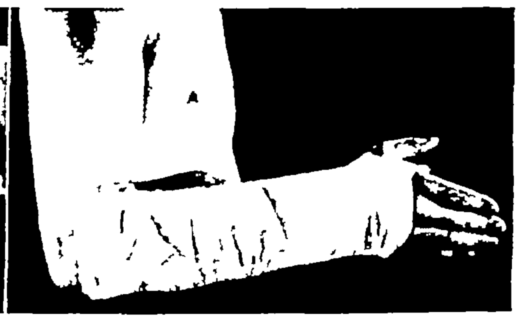


FIG 582—The joints above and below the splint are free

METHOD—The wire is cut long enough to extend from the tip of the fingers to the elbow It is applied along the front of the forearm. wrist, hand and fingers It is dorsi-flexed at the wrist, and palmar-flexed at the metacarpo-phalangeal and interphalangeal joints (Fig 583). The limb and splint are fixed by a bandage (Fig 584) It must be remembered that for metacarpal and phalangeal fractures this method is *only a first-aid measure* If it be used as a final method of treatment, severe stiffness results

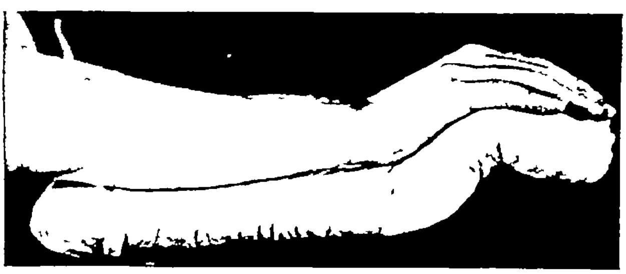


FIG 583—Limb and splint in position

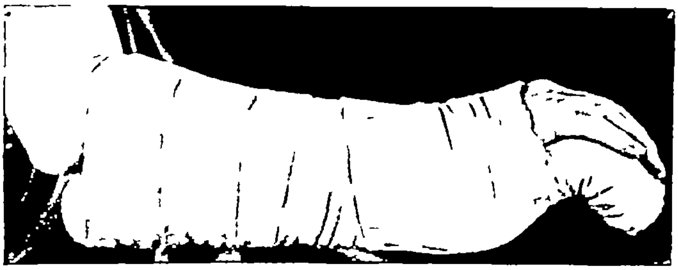


FIG 584—A bandage holds the limb and splint together

Fractures of leg—A single long piece of Cramer wire is sufficient

METHOD—The wire is bent to form a U as in the case of the humerus (Figs 568-573)

The splint is laid along the outer aspect of the leg and the level of the

heel marked. It is bent to a right angle at this level (Fig 569) Once more the wire is bent to an angle of 90° to form a U

This splint is then applied to the inner and outer aspects of the leg (Fig 585) It is fixed by a circular bandage (Fig 586) The forefoot is not

Fig 585—The U-shaped splint in position.

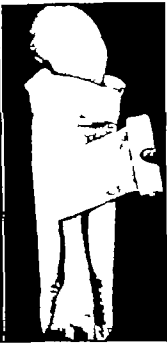


Fig 586—The bandage must be applied firmly

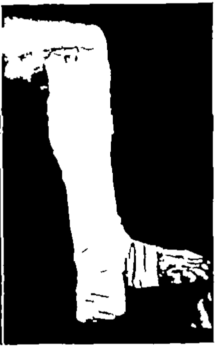


Fig 587—The leg splint applied.

Fig 588—The splint in place.

Fig 589—The splint fixes the ankle and foot.

included in the bandage The splint protrudes below the heel owing to the amount of padding It is fixed by figure-of-eight bandaging to prevent slipping (Fig 587)

Ankle and foot fractures—One length of Cramer wire is sufficient

METHOD—The wire is bent manually (Fig 569) to a right angle at the heel level. The splint is applied to the back of the leg and heel and along

the sole of the foot (Fig 588) A layer of wool is placed along the front of the leg and the dorsum of the foot Wool and splint are bandaged firmly in position (Fig 589).

Fractures of foot and leg—When both foot and leg are involved it may be necessary to combine both methods described above

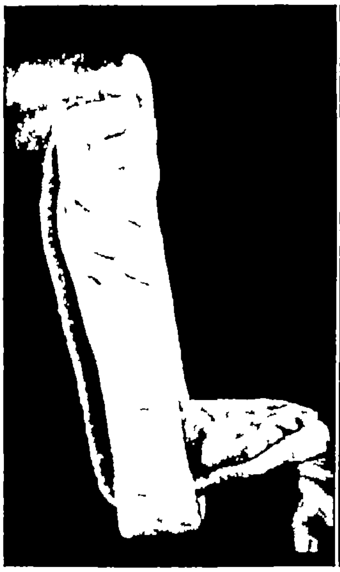


Fig 590
Leg and foot splint in position.

Fig 591 Fig 592
Both splints are fixed in position by a bandage

Method—The ankle and foot splint is applied first The leg splint is applied over it (Fig 590) A bandage is applied from above downwards and fixes the foot and leg No wool is needed except along the dorsum of the foot (Figs 591 and 592).

Transfusion—A single length of Cramer splinting is used

Method—The splint is laid along the back of the arm and forearm

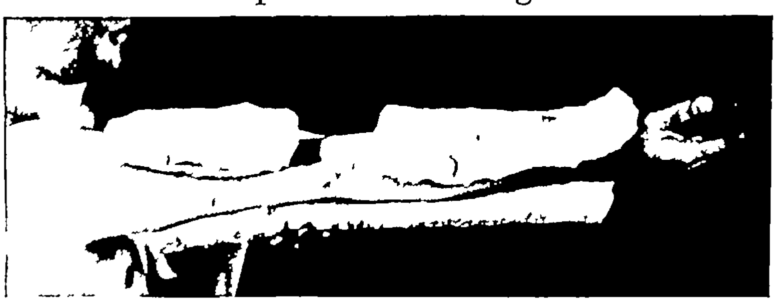


Fig 593
The position of splint and pads is shown

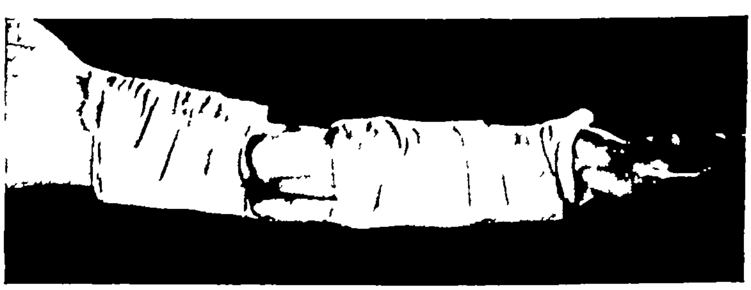


Fig 594
The elbow is fixed and the veins in front of the elbow are accessible The upper pad is bandaged loosely

The elbow is straight Pads of wool are placed on the front of the limb, above and below the elbow (Fig 593) The splint and pads are bandaged into position, leaving the region of the elbow-joint free (Fig 594)

THE AEROPLANE SPLINT

The uses of an abduction or aeroplane splint are nowadays limited It is used for a torn supraspinatus tendon fractures of the greater tuberosity of the humerus with wide separation of the fragments deltoid paralysis or œdema of the limb Very rarely is it necessary for fractures of the shaft of the humerus The Cramer wire splint is admittedly difficult to make but it is undoubtedly the most comfortable and the most efficient type of abduction splint

Four lengths of wire are required

Making the splint—MEASUREMENTS—

1 Iliac crest to axilla plus 4 in
2 From axilla to the outside of the flexed elbow
3 From the elbow to the knuckles

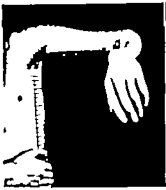


FIG. 595—The wire must extend downwards for 4 in. below crest of the ilium.

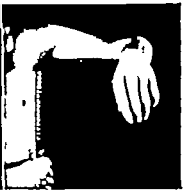


FIG 596—The buttress extends from elbow to ilium. Each end is bent to 45°

The first length—At the axillary level the wire is bent manually (Fig 569) to a right angle It is fitted to the arm to test the length (Fig 595)

The second length—The second piece of wire is used as a strut to buttress the first Four inches from one end it is bent to an angle of 45 and placed against the first piece at the ilium The opposite extremity is cut just beyond the elbow and also bent to 45 It is laid against the first length below the elbow (Fig 596)

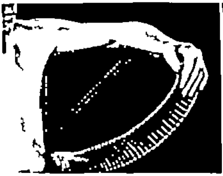


FIG 597—From the elbow to the knuckles this piece is straight, then curves to reach the ilium.

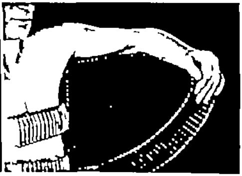
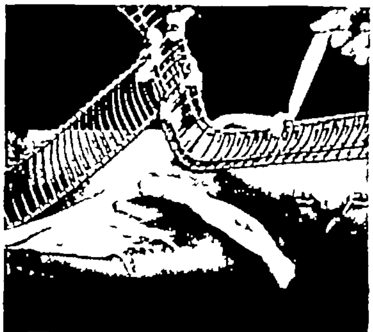


FIG. 598—The chest pieces are in place

The third length—One end of a wire length is placed between and at right angles to the others at the elbow It extends forwards along the under surface of the forearm to the knuckles Here it is bent to about 100 then it is twisted on itself so that it extends in a wide sweep to the ilium (Fig 597)

The fourth length—This is cut in half and applied to the first as two curved chest pieces They are 4 in apart (Fig 598)



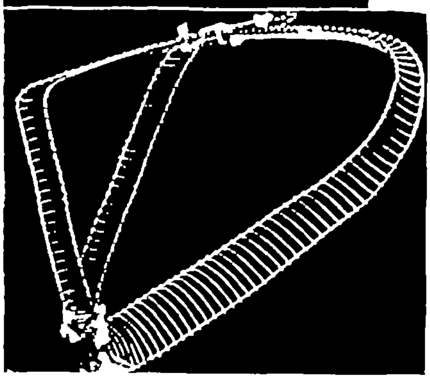


Fig 599—Fixing the ends with pieces of gauze bandage

Fig 600—How the junctions are fixed (The chest pieces are not included for clearness)

Joining the lengths—Various methods have been tried to fix the pieces together, such as soldering or wiring They are not successful The original idea of using 6-in lengths of gauze bandage is the best

At elbow, ilium and chest pieces the angles at the junctions are fixed by lengths of gauze bandage They are knotted firmly to hold the wires in place (Figs 599 and 600)

Padding—All the surfaces which come into contact with limb or body must be padded (p 643), so that the concavity of the wire is convex (Fig 566)

Applying the splint—Position—The splint is placed against the chest under the abducted arm An assistant keeps it pushed firmly into the axilla and in front of the coronal plane (Fig 601) Wool pads are placed over the sound shoulder and opposite sides of the chest (Fig 602)

Fixation—Six linen or domette bandages 6 yds long are needed

Bandaging—*The first two bandages* act as a sling A turn is taken round the iliac extremity of the splint, then it passes over the good shoulder and obliquely across the back to its starting point (Fig 602)

Fig 601
The splint is rotated forwards so as to be 30° in front of the coronal plane

Fig 602—The splint is pushed into the axilla Wool pads cover the opposite shoulder and chest Each turn of the first two bandages comes from ilium to opposite shoulder

The second two bandages—These are wound circularly round chest and splint (Fig 603)

The final two bandages—These pass alternately, obliquely, and circularly

The limb is fixed to the splint by a gauze bandage over a layer of wool (Fig 604)

Fig 603
Two 6-yd. bandages are applied circularly

Fig. 604—The splint is applied. The limb is fixed to the splint The fingers are free.

COVERING A PLASTER WINDOW

Nowadays plaster windows are not very popular but if they are used for the open treatment of wounds the best covering is a strip of Cramer wire

Method—A small piece of sterile gauze covers the wound and a suitable piece of Cramer wire is placed over the opening in the plaster (Fig 605)

Fig 605—The wire is cut and moulded to fit the window

Fig 606—Fixing the wire with a plaster bandage.

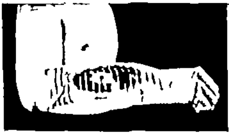


Fig. 607
The window completed.

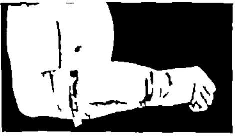


Fig 608—A gauze covering is fixed over the wire with strapping

A plaster bandage is then rolled on over the wire and window (Fig 606)

An aperture is cut in the plaster bandage and the small gauze dressing removed (Fig 607)

In peace time a dust-proof covering of cellophane is fixed over the wire A piece of dressing gauze is used as a war time substitute (Fig 608)

CRAMER WIRE BANJO SPLINT

This splint is only used for compound fractures, and then only when the skin on the anterior aspects of the fingers or either surface of the thumb is involved, and other splintage therefore impossible or undesirable

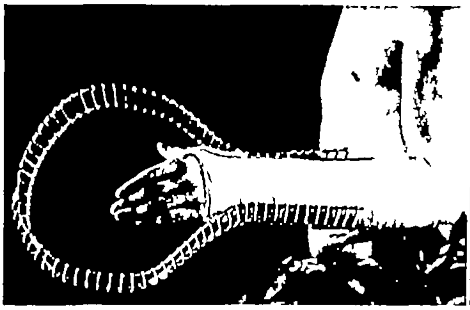


FIG 609—The wire fitted to the forearm

FIG 610—The wire is fixed by a plaster bandage

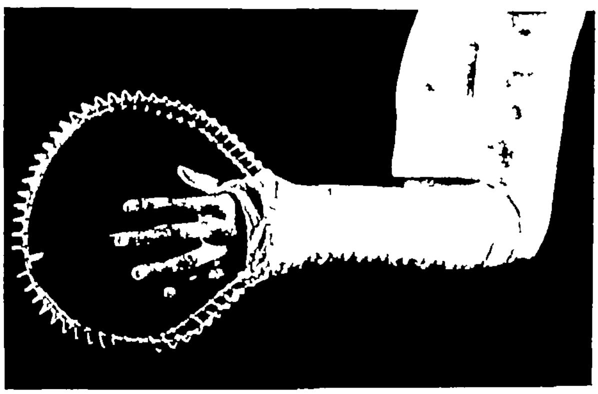


FIG 611—Extension maintained by pulp traction

Method—A forearm plaster is applied, then a length of Cramer wire is bent to resemble a banjo or tennis racket The handle fits along the forearm and the circular part surrounds the fingers (Fig 609) It is held in position by a plaster bandage (Fig 610) Extension is maintained by wire traction from the digit to the splint (Fig 611)

FIG 612—The cloth cover has been removed, showing the Cramer wire and its closely packed contents

CRAMER WIRE IN FIRST-AID KIT

The Germans have used Cramer wire in their Aircraft First-Aid Kit as the container for the remainder of the first-aid materials (Fig 612)

A large variety of materials are carried considering the small space available Fig 613 shows some of them removed

FIG 613—On either side are two slings on which are diagrams showing how to improvise various treatments, *e.g.*, the use of Cramer wire and a branch of a tree as a Liston s splint In the foreground is an amputation knife behind an Esmarch bandage wire cutters, scissors and plaster scissors in one Still in the container are bandages, plaster bandages, hypodermic injections, etc

When the contents have been removed the container can be used as a splint (Fig 614)

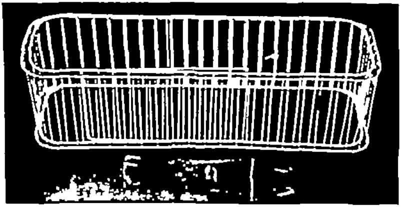


FIG 614—Cramer wire container and wire cutters.

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SECTION XIII

WOUNDS OF BONES AND JOINTS

CHAPTER LX

WOUNDS OF BONE

WOUNDS of bone cannot occur alone We are concerned here not with the treatment of war wounds in general but with those of a particular tissue of comparatively low vitality and absorptive power

The problem before us is largely the problem of the compound fracture upon which surgical attention has been focused both in times of peace and war since May 1866 It was in this month that Lister treated successfully a compound fracture of the leg by swabbing the wound with crude German creosote and covering it with plaster of Paris impregnated with the same chemical The day of conservative surgery in compound fractures had dawned

Remarkable progress has been made in this field and it is probable that finality has not yet been reached Perhaps even more than with other problems connected with war surgery it must be realized that sound judgment—when to operate when to amputate when to excise the wound meticulously and when to perform rapid but purposeful débridement—is far more important than blowing sulphanilamide powder around the broken bone and encasing the limb in plaster excellent as these procedures may be in their proper sphere

The time factor is the very crux of the situation The earlier a compound fracture can receive attention in the operating theatre the better the prognosis Every half hour counts In compound fractures of peace a limit of eight hours was generally conceded the maximum in which it was permissible after adequate cleansing to suture the wound in other words to convert an open fracture into a closed one It is doubtful if it is ever advisable to carry out this ideal in its entirety in war wounds except in selected cases of bullet wounds

Fig 613

A perforating wound of the lower end of the femur if situated within a hand's-breadth of the superior surface of the patella, may involve the knee-joint

Resuscitation is as important here as with other wounds To determine the mean between the urge to transfer the patient to the theatre in order to treat his local condition and the anxiety to retain him in the resuscitation ward for the improvement of his general condition is an occasion where a medical colleague with blood pressure and hæmatological records can be most helpful

Preliminary consideration of the case—Even when resuscitation is unnecessary there will be at least a quarter of an hour for the surgeon to

ponder and plan. He should assemble his data, bearing in mind that in every case of bomb and shell wounds it is probable that clothing and dirt will have been carried within. What was the condition of that clothing and the patient's skin? Is it possible that the neighbouring joint is involved (Fig. 615)? These are among the many points which should be occupying his attention.

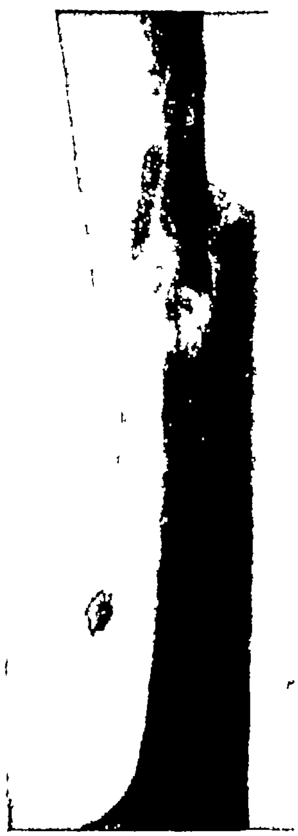


Fig. 616

Shrapnel causing compound comminuted fracture of the femur. (*Anthony Green.*)

Preliminary radiography.—Naturally it is of the utmost value to have before him radiographs showing the extent of the bone damage, and concrete evidence of retained foreign bodies (Fig. 616). Fissuring of the bone should be noted and special attention given to the possibility of a fissure entering a joint.

Should amputation be performed?—The whole trend of surgical progress is to save limbs, but it must be remembered that excessive conservatism may sacrifice a life. Decisions to perform amputation fall sharply into two categories:—

(*a*) Those made in the resuscitation ward from data which are manifest.
(*b*) Those which can only be arrived at after the wound has been explored.

It is not possible to embark upon the colossal task of enumerating the manifold combinations or circumstances which render amputation the best course. It is, however, necessary for the surgeon to always remember that the problems presented by a compound fracture in the upper extremity are entirely different from those in the lower. This is particularly the case when a decision has to be taken regarding amputation.

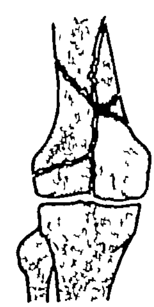


Fig. 617

Comminution of the condyles with fissuring into the knee joint with gross contamination is a type of compound fracture much to be feared. (*After Leriche.*)

It is clear that immediate amputation in the upper extremity is indicated only when the reasons are absolutely obvious. In early gross injuries excision, even drastic excision, of bone and joint can be undertaken. There is seldom a doubtful case in which the decision to amputate cannot be postponed for consultation with a colleague. Conversely, in the case of the lower limb, if there is no one available to share the responsibility and the surgeon is in real doubt, it is usually better for him to proceed with amputation. In the case of the lower third of the leg, for instance a badly comminuted, grossly soiled, compound Pott's fracture, the responsibility for amputation is not great and the decision is probably a wise one. In the case of projectile fractures of the femur, Sir Anthony Bowlby after an

immense experience gave the following helpful indications for amputation —

1 Wounding of the femoral or popliteal vessels which is unfortunately a common complication
2 Comminution of the condyles with involvement of the knee-joint (Fig 617) In very few cases should any attempt be made to save the limb in these circumstances
3 Extensive tearing and destruction of skin and muscle When large portions of the front or back of the thigh are torn off the limb would be useless even if it could be preserved

FACTORS WHICH INFLUENCE THE DECISION TO AMPUTATE

	Upper Extremity	*Lower Extremity*
Prosthesis	Almost valueless	Usually most satisfactory
Shock and poor general condition necessitating a rapid operation	Seldom enters the picture	Especially in the case of the femur a matter of grave concern.
Clothing	Coat and shirt sleeves usually comparatively clean	Trousers, pants, socks and boots often teeming with pathological bacteria
Concomitant arterial wound	Even when there is no pulse at the wrist, limb can often be saved	Femoral or popliteal arterial injury a matter for most serious consideration.
Operative reactionary and secondary hæmorrhage	Presents no difficult problem	All to be taken into consideration in compound fracture of the femur
Gas gangrene	Comparatively rare	Comparatively frequent
Infected phlebitis and embolus	Extremely rare	Sufficiently common for serious consideration
Considerable shortening	Of minor importance	Great handicap
Fracture involving joints	If necessary joint can be included in the resection with excellent results	Amputation sometimes indicated.

THE PATIENT'S GENERAL CONDITION AND THE TIME FACTOR PERMIT WOUND EXCISION

Instruments—It is highly desirable to have instruments arranged in three completely separate sterile groups —

(a) Instruments for general wound excision (see Chapter X)
(b) Instruments for bone purification procedures
(c) Instruments for skeletal traction (see Chapter XV)

Set (b) must include a few special bone instruments nothing elaborate is required A hammer a few gouges and chisels a Volkmann s spoon

sequestrum forceps and perhaps a pair of bone-holding forceps are obviously the type of instruments the Sister will put out The only special instrument to which attention is drawn, for it is a real asset, is Ollier's cutting rugine (Fig 618) or one of its modifications

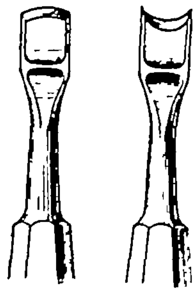


FIG 618
Ollier's cutting rugines

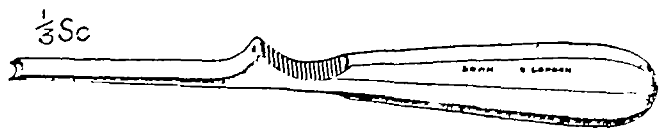


FIG 619
Pierpont's modification of Ollier's rugine

(Fig 619) The instrument should be of razor-like sharpness, and two or three are a surgical luxury

The Operation—The wound or wounds are covered with sterile gauze, while the large surrounding area of skin is washed, shaved and washed again, it is then painted with iodine or other skin antiseptic right up to the wound margin In a few instances where it is known that skeletal traction will be required, it is an advantage to commence by inserting the nail, after which the surgeon can proceed to utilize set (*a*) of his instruments without changing his gloves The wound is excised in the manner described in Chapter X When a missile has perforated the bone, comminution is frequently more marked on the side opposite the wound of entrance, and the soft parts there are more likely to contain bone fragments (Fig 620) Bone splinters must be searched for and removed from the muscles Before proceeding to deal with the bone itself gloves should be changed and set (*b*) of instruments used *It is most necessary to realize that in these cases* the medulla must be presumed to be contaminated, and in order to get at the medulla it is usually necessary to remove some bone This brings us to the question What should be done with fragments? All are agreed that completely detached fragments should be removed, and in the case of through-and-through wounds it is necessary to *approach the bone from both sides* Fragments still attached by periosteum should also be removed if by their removal adequate access is afforded to the medulla *On no account should such fragments* be picked up in forceps and twisted and torn from their moorings Fragments to be removed in order to afford access to the interior must be cleanly excised It is for this work that Ollier's cutting rugine is particularly suited It enables the surgeon to cut away with little injury enough bone to expose the medulla adequately Loose fragments and pulped medulla must be removed from the interior of the bone

FIG 620
The side farthest away from the wound of entrance is more likely to contain fragmented bone and foreign bodies
(*From a Radiograph*)

The question of how far to proceed in removing fragmented bone is debatable Towards the close of the 1914-18 war there were many converts

to the school of Ollier of which Leriche was and still is a great exponent Members of this school remove subperiosteally most if not all fragmented bone a process which they call *esquillectomy* Their main argument which is sound, is that unless splintered bone is removed sooner or later foreign matter lodged in a crevice will be overlooked Leriche believes that to perform esquillectomy neatly and thoroughly the Ollier type of instrument is essential and he maintains that serious infection cannot be prevented regularly except by complete clearance of fragmented bone He explains that early *subperiosteal* removal of fragments does not expose the fracture to the danger of pseudo arthrosis it is not a resection of the entire circumference but rather a removal of everything which interferes with complete exploration of the interior In more than two-thirds of cases the operation ultimately leaves the ends of the bone in continuity

Employing these principles, this authority was able to report a consecutive series of over 230 cases of comminuted, compound shaft fractures sustained in Flanders at a time when gas gangrene and profound sepsis were rife with the loss of only one case and without a single example of gas gangrene proof indeed that his ideas should not be passed by lightly

Irrigation of the wound—While many surgeons particularly American industrial surgeons of wide experience advocate and practise successfully irrigation of the wound with sterile saline at the conclusion of the surgical toilet the general consensus of opinion in this country is that irrigation should be eschewed In order to remove grit and fine débris moist swabs on holders are employed

Antiseptics—At the present time it is fashionable to regard antiseptics in a wound as lethal tissue poisons It is perfectly understandable that strong antiseptics can act in this way in any case they are quite unnecessary if wound excision has been carried out as it should have been. It is difficult to appreciate why some should look askance at swabbing the wound with a dilute solution of flavine or mercurochrome especially when control series have demonstrated that without doubt the incidence of post-operative sepsis is somewhat lower when an antiseptic is added to the ritual Be that as it may at the present time there is a wave of enthusiasm in favour of the local application of sulphanilamide powder When sulphanilamide is used the wound should be dried and the powder either applied with a dry swab or blown freely into the wound Clinical impressions and reports are so favourable that this addition to technique may be said to have become standardized

Should the skin be sutured?—As has been mentioned already it is wise to be cautious about closing the skin completely in the compound fractures of war Much depends upon the individual case If hæmostasis is entirely satisfactory and the surgeon has little doubt concerning the effectiveness of the excision and there is no tension upon the approximated skin much is to be gained by not too close suturing of the skin In other cases a few interrupted sutures can be placed and the wound drained by a strip of vaseline gauze or corrugated rubber In still others it is better to pack with vaseline gauze which does not preclude the possibility of secondary suture The whole question will become clearer when individual bone lesions are considered

Prophylactic sera—Before every operation for compound fracture antitetanic serum and antigas-gangrene serum should be administered in suitable doses, if this has not been done already

Immobilization—That every fracture, including every compound fracture, must be immobilized completely goes without saying As to how this immobilization is best effected depends upon circumstances Not the least of these are the surgeon's experience and training, the apparatus and nursing facilities that are available, and whether the patient has to be evacuated or remain under his care The closed plaster method has a great deal to recommend it, but we should not be blind to the fact that admirable results have been, and still are obtained by other methods In certain instances other methods are to be preferred The best means of taking a broad view of the whole subject is to consider compound fractures of individual bones

COMPOUND FRACTURES OF INDIVIDUAL BONES

Tibia—Böhler's screw traction apparatus (p 639) is rightly popular and is now widely available It is a good practice to commence by inserting a Steinmann's nail through the os calcis and then to attend to the necessary excision of the wound and the toilet of the fracture with the limb on the apparatus Having covered the wound with strips of vaseline gauze, a plaster cast is applied (see p 604) Stockinet is omitted, but bony prominences are well protected by best quality felt Because of the danger of interference with the circulation consequent upon post-operative œdema, the plaster should be guttered (see p 595)

Alternatively the Böhler-Braun splint can be employed, especially—

(*a*) When circumstances are favourable and there is sufficient skin to permit of closure of the wound without any tension

(*b*) In doubtful cases nearing the time limit where infection is feared In this instance the question of suturing the wound does not arise

Whether a plaster has been applied or not, elevation is desirable, and for this purpose a Böhler-Braun splint cannot be bettered When circumstances permit, probably the best method for all cases is to defer applying a plaster for a few days, during which time the Böhler-Braun splint is employed After approximately four days the danger of post-operative swelling has passed, and also the danger of spreading infection

Fibula—When the fibula is involved alone there is hardly a more satisfactory bone to treat Large portions of the shaft can be removed by subperiosteal resection without fear of loss of function At the upper end the external popliteal nerve must be cared for, at the lower end the external malleolus should be preserved if possible The immediate application of a plaster cast cannot be bettered

Patella—Excision of the patella with suture of the capsule and the immediate application of a plaster cast is eminently satisfactory

Femur—This of course is the most difficult problem connected with compound fractures The main indications for amputation have been

discussed on p 608 When there is the slightest doubt concerning the vascular integrity of the limb under no circumstances should plaster be employed until the danger of gangrene has passed. In grave cases or compound fractures of the upper third when the patient s general condition is

Fig 621
The danger area through which intervention should not be undertaken. When necessary a fresh incision is made (*After Leriche*)

poor in spite of resuscitative measures the reader s attention is directed to the sleeve amputation (see p 761)

We will assume that the patient s general condition is sufficiently good to withstand a fairly prolonged operation under gas-oxygen-ether anæsthesia because of incipient shock a spinal anæsthetic is to be deprecated in these cases Suitable exposure is of major concern and it may so happen that the wound is not the best avenue of approach Fig 621 emphasizes this point and in certain cases after the wounds have been excised it is advisable to make a fresh incision with uncontaminated instruments

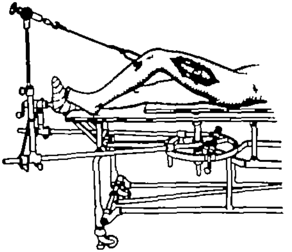


Fig 622
When an orthopædic table is available it is an excellent practice to insert a Steinmann s nail through the crest of the tibia. The wound is then excised and the whole operation, including the application of the plaster cast, completed. Note the flexion of the knee and the hip. (*After Trueta*)

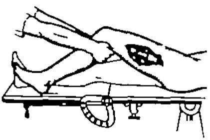


Fig 623
In the absence of an orthopædic table an assistant can maintain the desired position. (*After Trueta*)

The results of closed plaster treatment are most encouraging If an orthopædic table even the portable variety (p 592) is available there is a great deal to be said for commencing by inserting a Steinmann s nail through the crest of the tibia To have the knee and, to a lesser extent the hip flexed together with suitable traction definitely aids the necessary surgical attention to the bone ends and helps to get them into alignment When an orthopædic table is not to hand, an assistant with his hands clasped under the knee (Fig 623) can be an efficient substitute In grossly

contaminated but early cases, drainage of the deep fascial planes, which will be detailed on p 666, must receive consideration There is no serious objection to including a drainage tube within the plaster cast, providing its presence is notified in writing on the cast The plaster is applied with the hip and knee still flexed and it extends from the lower ribs to the heads of the metatarsal bones, the sole of the plaster extending beyond the tips of the toes to prevent pressure from the bedclothes (Fig 624)

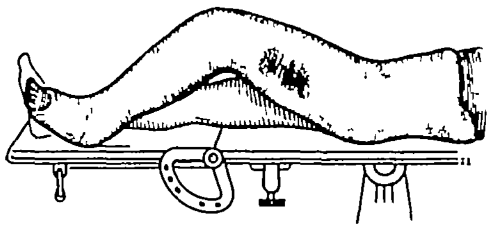


FIG 624

The plaster cast for compound fracture of the femur completed Note the position of the limb (*After Trueta*)

Even a patient in comparatively good condition is likely to show some recrudescence of shock after this formidable procedure It should be understood that plaster, in setting, generates heat and for the time being serves a useful purpose in keeping the patient warm It is, however, highly important when the patient is returned to the ward to ensure that the plaster is not dried at the expense of extracting heat from the patient On the other hand, nurses must not be allowed to cover the patient with blankets, for this will delay drying of the plaster Air must be allowed to circulate, and the best method of both attending to the patient's needs and at the same time drying the plaster is to apply a radiant-heat cradle

It should not be lost sight of that thousands of excellent results have been obtained by the use of Thomas' splint and Braun's splint The latter has the serious disadvantage of being unsuitable if the patient is to be evacuated For severely shocked patients, especially in cases of compound fractures near the upper end of the bone, Thomas' frame is without doubt the best expedient Summarizing the position the closed plaster is the best method to employ when the patient's general condition is satisfactory and the necessary facilities for its rapid application are to hand Experience in plaster work is particularly desirable, to apply a hip spica properly requires as much training and experience as to perform a gastro-jejunostomy correctly

Humerus —These injuries are much more common in war than in peace As pointed out already, in this instance the bone lesion *per se* is seldom, if ever, an indication for amputation, it is concomitant devastating injuries to vessels and particularly nerves which are the determining factors in deciding that the limb must be sacrificed Compound fractures of the upper third (*i e*, above the musculo-spiral, syn radial nerve) are particularly favourable lesions to treat In the middle third the musculo-spiral nerve is prone to be damaged, but this does not preclude the possibility of saving a useful limb Unfortunately, in the middle third, main vessels are liable to be damaged almost irreparably The same remarks apply even more forcibly to the lower third of the bone As emphasized already in this chapter, if necessary a considerable area of contaminated bone, which may even include a joint, can be excised with every prospect of ultimately securing a limb with considerable function

The closed plaster technique is eminently suitable for compound fractures

of the humerus the major deterrent to its use is the difficulty of applying a thoraco brachial plaster cast to an unconscious patient To apply it quickly and efficiently the patient must be in the sitting posture or on an orthopædic table The difficulty can be overcome thus the wound is excised and the bone treated appropriately The arm is then placed upon a temporary splint and for this purpose there is no better splint than one constructed of Cramer wire (p 649) These aeroplane splints useful as they are and however well constructed are not sufficiently stable to ensure complete immobilization a plaster cast is infinitely superior in this respect As soon as the patient has recovered sufficiently local block brachial anæsthesia is induced after suitable premedication With the patient in the sitting posture the plaster is applied

BRACHIAL BLOCK ANÆSTHESIA—As the brachial plexus passes beneath the clavicle it lies just external to the subclavian artery The patient is seated with the face turned to the opposite side and, if possible with the shoulder depressed. A cutaneous wheal of local anæsthesia is raised just above the mid point of the clavicle immediately external to the (often palpable) subclavian artery A larger needle is then introduced, pointing it towards the second dorsal vertebra. The needle should not be attached to the syringe while the search for the plexus is being made After the needle has traversed the fascia it is advanced slowly; it is, of course, essential to withdraw at once if blood appears. When the nerve plexus has been entered, the patient will experience tingling sensations The first cord likely to be struck contains the fibres going to the median nerve The most complete anæsthesia follows injection of the cord containing the ulnar nerve and paræsthesia will be experienced in the fourth and fifth digits. Once the needle is satisfactorily in place it must be kept in position until the syringe can be attached and the injection made Farr recommends steadying the needle with a rubber-covered hæmostat (Fig 623) Having fixed the syringe containing 10 c.c. of 1 per cent. novocain to the needle, and after being quite certain by attempting to aspirate blood that the point of the needle is not within a vessel, the contents of the syringe are injected slowly During the last third of the injection the needle is withdrawn slowly

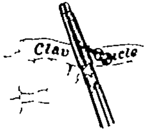


FIG 623

In order to steady the hollow needle it can be grasped with a rubber covered hæmostat (*After Farr*)

The patient is seated on a low backless stool and the surgeon sits facing the patient and the assistant sits behind the patient A second assistant holds the arm in the desired position Surgeons who had great experience of this method in the Spanish war are unanimous that the optimal position for immobilization is one of 45° abduction (Fig 620)

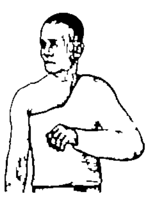


FIG 620

Thoraco brachial plaster applied Note the optimal position (45 abduction) (*After Jolly*)

If the arm is placed in this position with the forearm flexed to a right angle and in the position of neutral pronation and supination the fragments will nearly always be in true alignment (Jolly) In necessary cases suitable precautions to prevent wrist-drop must be taken

Radius and ulna—If one bone alone is damaged particularly the ulna the case presents comparatively little difficulty In necessary cases large portions of these bones can be removed with every hope of an excellent functional result In the case of the radius tense fascial planes surround this more deeply placed bone and attention must be directed to ensuring adequate drainage A plaster cast extending from the deltoid region to the metacarpals is an admirable form of immobilization When both bones are

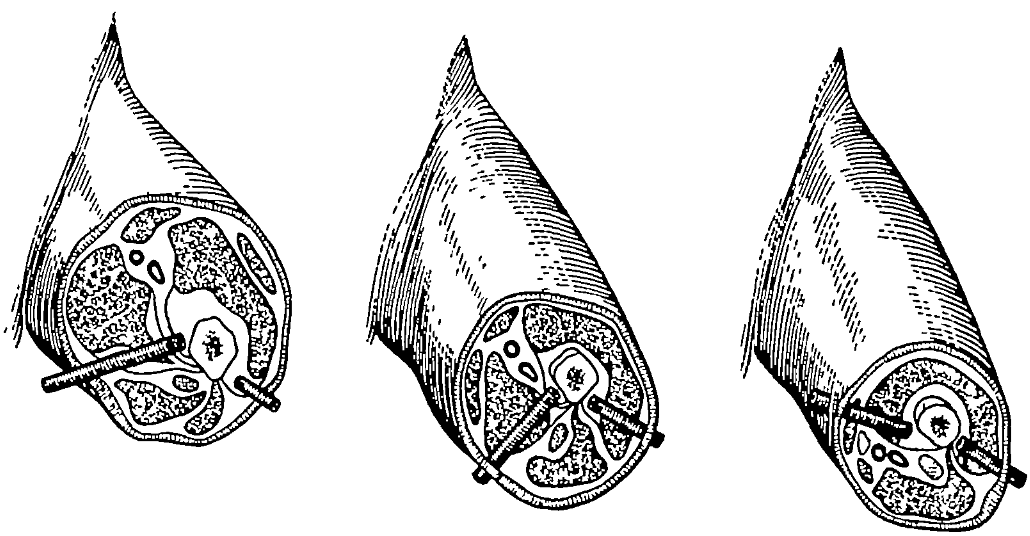
fractured the position of full supination should be employed, otherwise the arm is immobilized in the neutral position

THE TREATMENT OF LATE CASES

It has been emphasized throughout this work that wound excision must not be attempted after eighteen hours This time limit is, of necessity, somewhat arbitrary, and cases round about the demarcation period naturally present perplexity When signs of visible infection are manifest, no doubt arises as to the correct lines upon which to proceed In other instances it is always well to hold a consultation with a colleague

Cases visibly infected can be divided sharply into two categories —

(*a*) Those with signs of toxic absorption
(*b*) Those without such signs



UPPER THIRD MIDDLE THIRD LOWER THIRD

Fig 627

Showing the correct position for inserting drainage tubes in the upper, middle and lower thigh respectively Usually only one tube is required (*After Böhler*)

In both the need for débridement of the wound is imperative By " débridement " is meant what has been insisted upon throughout this work—the original interpretation of the term—namely a rapid operation designed to open infected fascial planes, provide free drainage and remove foreign matter and tissue unquestionably dead As far as the bone part of the operation is concerned loose fragments must be removed, and it is highly desirable to excise enough but no more of the fragments attached by their periosteum to ensure free drainage of the medulla Drainage tubes are seldom employed, but in the case of the femur, according to the best authorities, it is often desirable to utilize them, for the overlapping muscles often make proper drainage impossible through the wound Fig 627 shows the best positions for placing soft rubber tubes in the case of the upper, middle and lower thirds of the thigh respectively The same principles

are invoked in a few other situations where common sense dictates that pocketing is liable to occur

A When signs of considerable toxæmia are manifest and particularly if anaerobic organisms are the cause the closed plaster technique is definitely contraindicated Open treatment in every sense of the word is the order of the day The wound must be freely open and irrigation by the Carrel Dakin method or one of its substitutes cannot be bettered Certainly sulphonamide therapy should be instituted at once but in this instance by common consent its local application is without value

B In visibly infected wounds without marked toxæmia the closed plaster technique after débridement is highly successful Indeed it is in these cases that it reaches its zenith of usefulness and displays the manifold advantages of a great advance The wound should be so packed with strips of vaseline gauze as to provide avenues for the freest drainage possible In necessary cases there is no objection to incorporating within the plaster cast one or two drainage tubes if without their aid a closed pocket is inevitable Naturally if signs of toxæmia develop the plaster cast must be removed but there should be no undue alarm concerning a patient with a raised temperature if his general condition remains good and above all if his pulse is comparatively unaccelerated and he does not complain of pain

As the days go by the one major objection to the closed plaster—the appalling stench—will doubtless be brought to the surgeon s notice in one way or another Many attempts have been made to overcome this objection A method offering some hope of reducing the malodour was introduced by the Strasbourg school It consisted in placing in the wound a tampon containing a mixture of yeast and agar which had been deproteinized

Professor Seddon working with Professor Florey at Oxford tried a number of methods to overcome the smell. The material now known as Filter Cloth (Medical) has proved to be the best As a result of confirmatory trials organized by the War Wounds Committee of the Medical Research Council, it is agreed that this cloth when made in the form of a bag enveloping the plaster cast is the best smell preventer available and many thousands of yards have been ordered for use in British hospitals at home and overseas

When the plaster is changed if adherent sloughs are in evidence the advantages of maggot therapy (Chapter XVI) should not be forgotten

SEQUESTRA

Experience of the 1914 18 conflict left no doubt that sequestrum formation and its treatment was a major surgical problem destined to occupy attention for years after the declaration of peace Although by correct treatment the patient s life and limb may be saved, once a compound fracture becomes grossly infected, neither adequate drainage nor anything else we may do is likely to obviate death of some portion of the bone sequestrum formation (Fig 628) must be expected

When to operate—It is a common error to attempt to remove a sequestrum too early Especially in the case of the shaft of the femur or the humerus sufficient time must elapse for the involucrum to become consolidated otherwise the risk of fracture following sequestrectomy is

considerable Again, if the sequestrum is not loose, its extraction is likely to traumatize living bone in juxtaposition and, what is perhaps even more important, under these conditions sequestrectomy will be almost certainly incomplete Within reasonable limits the longer the operation is deferred the easier it is to execute

Fig 628
Sequestrum following a guillotine amputation of the femur
(*Hugh Donovan s Case*)

Undue delay is also likely to result in a sclerosed involucrum, making healing difficult, in addition the surrounding soft parts become so encased in fibrous tissue that the blood supply to the new bone is impaired These factors tend to cause recurrence and chronicity after sequestrectomy The time at which the operation is performed is, therefore a matter of real importance and must be well chosen While varying within wide limits, twelve weeks after the primary operation is the optimum time in the case where there is a parallel bone to act as a splint (*e g* , tibia

Fig 629
The ripening of a sequestrum Compound fracture through the neck of the astragalus involving the ankle joint and the subastragaloid-joint

A, Eighteen days after the *injury* Showing *decalcification of bone in the vicinity*, except the body of the astragalus

B, Seven weeks after the injury Decalcification continues in all bones of the leg and foot, but the body of the astragalus retains its original density, and it must be either dead or hibernating

C, Fifteen weeks after the injury The opaqueness of the body of the astragalus makes it definite that it is a sequestrum

ulna) In the case of the humerus, femur, clavicle and mandible, when the entire circumference of the shaft is jeopardized it is advisable to wait longer

In assessing the optimum time to operate the first consideration is the

patient s general condition If it appears that freer drainage and removal of at least some dead bone will obviate progressive toxic absorption then the course is clear—an operation must be designed to effect this end with the least possible trauma

In other and more usual circumstances a plan is made not only to rid the patient of the sequestrum but to effect a permanent local cure which is not by any means always a simple matter

In apprizing the local condition the following are extremely helpful —

Serial radiographs often reveal gradual separation of the dead bone from the surrounding involucrum of new and imperfectly formed bone (Fig 629) While radiography is of the greatest possible assistance the films are some times difficult to interpret in all cases it should be only a factor—a highly im portant factor—in making a decision that the time is ripe for sequestrectomy

Probing is often extremely valuable in determining that a sequestrum is loose The probe comes in contact with hard and bare bone Bareness does not mean that it is dead The sensation is that there is nothing whatsoever between the probe and the bone If the bone is bare but alive the impression is that there is a thin film of soft material (granulations) between the bone and the probe If the dead bone be loose pressure with the probe may cause it to move

SEQUESTRECTOMY

Special care must be taken to avoid nerves large vessels and the near by joint Adequate access to the bone is essential at the same time the approach must be designed to be as direct as possible At the end of the operation saucerized bone—by which is meant that there are no overhanging bone edges—should lie at the bottom of the wound (Fig 630)

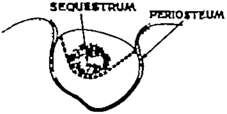


Fig 630
Ideal sequestrectomy

The ideal can seldom be attained except in superficial bones (tibia ulna) but by correct technique and particu larly by a carefully planned anatomical approach much can be done to create a channel from the skin surface to the marrow cavity of the type which experience has shown helps to minimize the bugbear of these cases—recurrence and chronicity With this object in view when designing the approach the situation of sinuses and the site of the original wound fade into comparative insignificance If one or other of these exits can be incorporated in the new incision so much the better if not they are disregarded in favour of an incision which is farther away from large nerves and blood vessels and yet provides the best access and freest drainage

TECHNIQUE—GENERAL

A bloodless field is desirable—In situations where a tourniquet is applicable it should be employed Even so in some situations loss of blood is likely to be considerable after the tourniquet has been removed. As by reason of the long-continued sepsis these patients are often ill prepared to withstand loss of blood it is essential to have blood grouping carried out and arrangements completed for an immediate transfusion should it become necessary

The limb must be stabilized—Attention must be directed to placing the limb upon a sandbag in the most convenient position for the selected approach and to seeing that it is maintained firmly in that position throughout the operation (Fig 631)

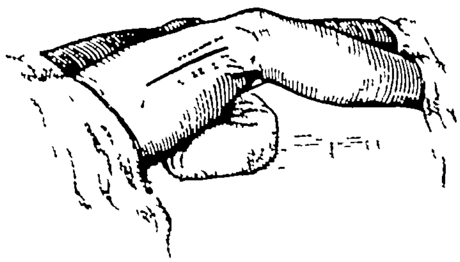


Fig 631
Showing the position and incision for sequestrectomy of the lower end of the femur

Radiographs should be at hand—Especially in cases where there is more than one sequestrum it is essential to be able to refer to the X-ray evidence during the course of the operation

Unbridled stripping of the periosteum is to be deprecated—It is necessary to uncover a liberal area of the bone—an area which extends longitudinally beyond the extreme limits of the sequestrum, and it is also necessary to bare the bone in the opposite plane, but it is seldom necessary to strip more than one-third or at the most one-half of the circumference Accurate periosteal elevation is more likely to accrue from the use of a sharp instrument than a comparatively blunt elevator

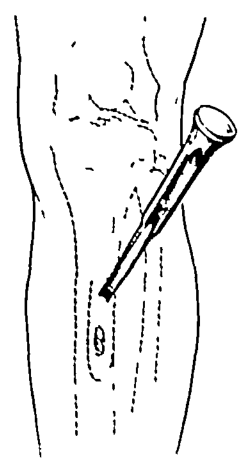


Fig 632
Sequestrectomy Showing the approximate area in relation to the sequestrum in which to commence removal of the bone

Opening the bone is effected with a gouge—several sizes should be at hand, as a rule a relatively broad one is chosen The amount of hammering and chiselling to be done varies enormously (Fig 632) In the case of a patient who has been absorbing toxins possibly for months from a deeply seated sequestrum of the femur, such a procedure is likely to be associated with a good deal of shock and it may be wise to undertake the operation in stages (Phillips)

Usually the bone should be removed over the whole length of the sequestrum, which if loose is then extracted easily (Fig 633) Removal of a large sequestrum is sometimes facilitated by dividing it into two or more parts Granulation tissue surrounding the sequestrum should be disturbed as little as possible for it contains elements important in subsequent regeneration Only when it is probable that there are other sequestra or an abscess behind it should the granulation tissue be disturbed

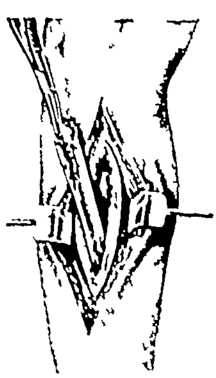


Fig 633
Extracting a sequestrum with sequestrum forceps

Saucerization—By removing all dead bone (which should be loose if the time for sequestrectomy has been well chosen), by preserving the integrity of the periosteum of at least half of the circumference, and by refraining from curetting granulation tissue much will be done to favour eventual healing without recurrence There is however, one more most important duty, that is if possible to saucerize the bone Overhanging bone edges must be cut away so as to leave a cavity with gently sloping walls To convert the

bone defect into a trough at least a third and sometimes nearly a half of the circumference of the shaft must be chiselled away (Fig 634) In the case of round bones such as the humerus and the femur there is natural hesitation to sacrifice what may appear to be an undue amount of involucrum Such hesitation in the case of unsupported bones (femur humerus) is sometimes well founded for in spite of waiting patiently for weeks or months the involucrum may be too fragile to withstand drastic reduction It is in cases such as these that 'stage operations can be contemplated Obviously there are cases where anatomical considerations or the nature of the disease limits this method of choice Take for instance the lower end of the femur where it is so necessary to keep away from the cavity of the knee-joint Here the gouge and the chisel are dangerous instruments and recourse must be made to the older method of sharp curettage to remove as much as possible of the over hanging bone (Fig 635)

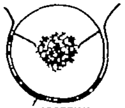


FIG 634

Saucerization. Showing the amount of periosteum and bone which must be removed in order that the procedure may be efficient Note particularly that the periosteum is not stripped farther than is necessary

FIG 635

When chiselling is dangerous a sharp Volkmann s spoon must be used to pick away overhanging bone edge. (*After Kirschner*)

So it comes about that in spite of unimpeachable judgment and perfect technique there will always be some cases of recurrence and failure to heal The latter will occupy our attention presently

Dressing and immobilization—Having completed the operation by rendering the trough as mechanically sound as circumstances permit the whole wound is plugged with gauze which is then pulled out to make certain that it does not get caught upon a sharp edge which has been overlooked The gauze packing is again inserted and the tourniquet is removed By withdrawing the gauze slowly some help in locating spurting vessels is afforded

It was for cases of chronic osteomyelitis that Winnett Orr first framed his closed treatment Whatever may be the merits and demerits of the method in other conditions there is abundant agreement that it is *the* treatment after sequestrectomy In our opinion it is best to adhere to the Winnett Orr technique The whole cavity is packed with vaseline gauze another piece of vaseline gauze is spread over the area Vaseline is smeared lightly on the skin for a considerable distance around A plaster cast which will ensure complete immobilization of the part is then applied B I P P or modified B I P P in the wound as favoured by some has the disadvantage of obscuring X ray studies of bone regeneration

TECHNIQUE—INDIVIDUAL BONES

Tibia—The tibia is one of the easiest bones upon which to perform ideal sequestrectomy This is fortunate for it is one of the bones upon which the operation is most frequently required A tourniquet can be used with perfect

satisfaction and in this instance undue hæmorrhage, either immediately or during the post-operative period, is improbable The skin incision should follow the middle of the antero-internal surface When chiselling, as much of the crest as possible should be retained, for this is the strongest part of the bone

Fibula—Partial or complete subperiosteal diaphysectomy, with or without primary suture, is the method of choice Care must be exercised to preserve the integrity of the external popliteal nerve as it winds round the neck of the fibula The lower end (external malleolus) must be preserved whenever possible

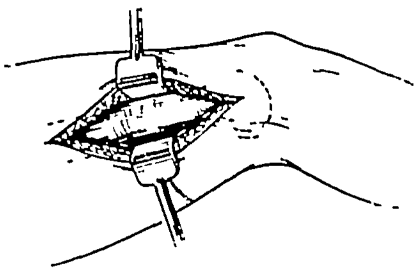


FIG 636

Sequestrectomy lower end of the femur The integrity of the capsule of the knee joint should be a cause of constant vigil To this end the incision through the muscles must not extend lower than an inch above the external condyle

Femur—LOWER THIRD—The position of the limb upon the operating table is shown in Fig 631 An incision passes through the muscles (Fig 636) not lower than an inch above the upper edge of the lateral condyle and is extended up as far as necessary Constant watchfulness is necessary that the cavity of the knee-joint or its various synovial pouches are not entered When the sequestrum lies on the popliteal surface of the bone chiselling proceeds towards the popliteal space until the angle between the lateral and the posterior surface of the bone is reached (Fig 637) With suitable retraction and protection of the soft parts, chiselling can now be undertaken until the sequestrum is in view in the depths of the space

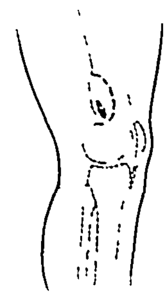


FIG 637

Showing the area of bone to be removed when the sequestrum lies on the popliteal aspect of the lower end of the femur

MIDDLE THIRD—The incision follows a line between the tip of the great trochanter and the outer border of the patella It passes straight through the muscle in the line of the incision No vessel of any great size is encountered and the incision gives excellent exposure of the bone

UPPER THIRD—This is probably the most dangerous area of the body from which to remove a sequestrum The particular danger is hæmorrhage and special precautions are always necessary An elastic tourniquet is placed as high as possible In order to prevent the tourniquet slipping two strips of bandage are placed beneath the tourniquet and these are held taut throughout the operation by an assistant pulling towards the patient's opposite shoulder (Fig 638) On a few occasions where the disease has been too high for the adequate fitting of a tourniquet preliminary ligature of the internal iliac artery and the profunda femoris artery can be performed a precaution which has proved of great service in connection with the removal of tumours at the upper end of the femur The best exposure is afforded

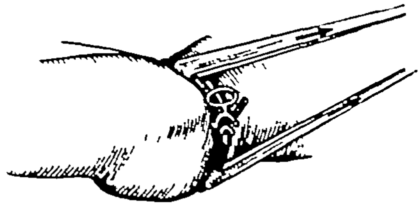


FIG 638

A method of keeping a very high tourniquet in place The loops of bandage are held throughout the operation by an assistant at the head of the table

by a vertical incision through the fascia lata on a plane with the fore part of the great trochanter

Pelvic girdle—The pubic bone deserves some special attention Leguen and Marion during the 1914 18 war called attention to the clinical entity intractable cystitis following compound fractures of the pubic bones (Fig 639) No improvement can occur until the bone necrosis is eradicated The sequestrum must be removed and free drainage provided for the tissues about the cave of Retzius The bladder itself must if possible be separated from diseased bone Deviation of the urinary stream is accomplished by suprapubic cystostomy with the opening into the bladder as far as possible from the necrotic pubis Cystostomy drainage must continue until the sinuses connected with the bone have healed (Mathé) (see also p 445)

FIG 639
Intractable cystitis following fracture of the pelvis is a clinical entity Typical X ray appearance in this condition (*After C P Mathé*)

Ulna—This being a subcutaneous bone supported by a parallel bone it is perhaps the most favourable of all bones upon which to perform ideal sequestrectomy

Radius—LOWER THIRD—An incision between the brachio radialis and the extensor carpi radialis longior exposes at least the lower third of the lateral aspect of the bone and gives better drainage and more adequate exposure than an incision between the brachio radialis insertion and the radial artery

MIDDLE THIRD—The posterior surface of the middle of the shaft can be reached between the insertion of the pronator radii teres and the origin of the abductor pollicis longus The route is to the lateral side of the extensor communis digitorum and by retraction of the abductor pollicis longus

UPPER THIRD—This can be reached by a prolongation of the above incision upwards *as far as the external epicondyle of the humerus By dividing the extensors the supinator brevis is exposed Buried in the supinator* brevis is the posterior interosseous nerve however the supinator brevis has to be divided in order to reach the upper end of the radius It is wise to keep the division of the supinator brevis close to the ulna and then retract the main portion of the muscle upwards to uncover the radius If the section of the supinator brevis be made too far forward for example on the lateral aspect of the radius there is very great risk of injury to the posterior interosseous nerve either by the scalpel or by retractors

Humerus—LOWER THIRD—The bone can be reached quite adequately posteriorly by an incision splitting the triceps muscle parallel to its fibres Here again it is wise to open the periosteum well above the upper margin of the olecranon and work from above downwards when stripping it so as to make sure that the olecranon fossa and the synovial membrane of the elbow joint are not opened

MIDDLE THIRD—The safest route is between the biceps and the insertion of the deltoid in its upper part and along the outer border of the biceps in its lower part In the lower part of the incision one proceeds warily for

fear of injuring the musculospiral (syn radial) nerve The surface marking of the musculospiral nerve is shown in Fig 640 It is an excellent practice to divide the periosteum first in the upper part of the incision and then work from above downwards It is better to reach the lower parts of the middle third by undermining the periosteum than to run the risk of cutting the musculospiral by too free an incision in the soft parts

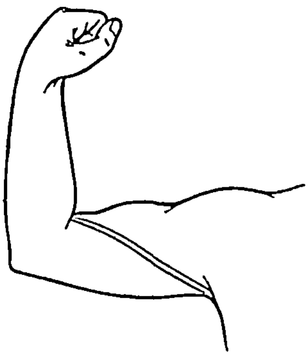


Fig 640
The surface marking of the musculospiral nerve

Upper third—The incision lies between the pectoralis major and the deltoid The guide when the skin is divided is the large cephalic vein which, in muscular subjects, may be covered by the overlapping edge of one of the muscles, but which nevertheless must be found Moreover, it should be preserved, as it constitutes an alternative route for the circulation should there be any pathological change in the axillary vein Although the upper end of the humerus can be reached at the posterior margin of the deltoid, such a route endangers the circumflex nerve and blood vessels to the deltoid muscle (see p 679)

Clavicle and lower jaw—Both these bones are virtually subcutaneous, and the incision must be made so as to get an adequate exposure of the field of operation but at the same time be hidden as much as possible from a cosmetic point of view

METHODS OF OBLITERATING BONE CAVITIES

By adopting modern methods of sequestrectomy the number of cases where it is necessary to direct attention to this matter has fallen appreciably It has been emphasized that if ideal sequestrectomy can be performed, healing can be expected under the Winnett Orr treatment Further, it has been shown that ideal sequestrectomy with saucerization may be impossible—

(*a*) Because the involucrum is judged to be too fragile to withstand drastic reduction Such cases may eventually become suitable for saucerization at a second operation
(*b*) Because in certain situations the anatomical arrangement renders the method impracticable

The array of heterogeneous methods which have been suggested to obliterate a bone cavity is formidable It invokes admiration for surgical ingenuity, but arouses suspicion that none is eminently satisfactory While admitting that there is a modicum of truth in this assumption, the reader must realize that no two bone cavities are exactly alike, and within limits it is a great advantage to be familiar with a variety of methods What may prove a brilliant success in one may be profoundly disappointing in another It is often the operator's choice which is at fault rather than the method

Filling with foreign material—Daily the dental surgeon fills cavities rendered tolerably clean with gold and alloys These fillings commonly remain trouble-free for a long lifetime It is the conviction of the majority

of present-day surgeons that to leave foreign material in any tissue contravenes those physiological principles upon which modern surgery is based

Murphy's button Lane's plates and the silver filigree are a few of the foreign materials which have been relegated to the museum It is therefore not surprising to find that filling bone cavities with unphysiological matter has a dwindling advocacy A variety of substances have been used as fillings Mosetig Moorhoff's wax (iodoform 60 spermaceti 40 oil of sesame 40) melted pure sulphur resin Dermatol are but a few Most with whom this method still finds favour now employ ordinary plaster of Paris sterilized dry and then mixed with sterile water and perhaps a little iodoform or other antiseptic (Alessandri)

There is also much to be said in favour of a material which can fill every nook and cranny of an awkward cavity and yet is not a foreign material in the ordinary sense this is sterilized mutton fat It can be melted and poured into the defect in a liquid state and will set at body temperature The type of cavity in which this form of filling is indicated is a deep seated cupped cavity which is obviously unsuited to saucerization Such a cavity might be found during a primary operation for sequestrectomy of the Brodie's abscess type In the filling of a cavity with extraneous material those principles which the dental surgeon employs including finally drying the cavity with hot air help to secure success

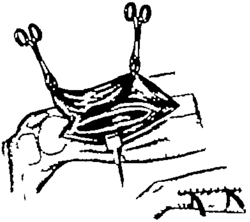


FIG 641

Muscle flap for filling a cavity in the femur (After Lord.)

Pedicle muscle graft—The particular indication for a muscle graft is a large tunnel in the bone with an overhanging edge or edges which cannot safely be removed the bone being a mere shell. Once again this type of case will be met with more frequently at a primary operation of sequestrectomy With older wounds where packing and plaster have been resorted to it is difficult to get an adequate muscle flap (Fig 641) A muscle *flap* is a happy term for it implies that the muscle must have a broad attachment with an ample blood supply A muscle attached at one end dangling in the bone cavity is worse than useless it soon dies and adds its toll to the septic morass The muscle flap must be of such a size as to more than fill the cavity there must be no recesses in which blood can collect In order to keep the muscle mass *in situ* it may be advisable to drill the bone in two or three places to pass sutures through the muscle and out through these holes

Lord advises closure of the skin wound about an entrance and an exit rubber tube which passes into the bone cavity For the first twelve hours after operation the wound is irrigated with sodium citrate in order to obviate collection of clotted blood (Fig 641 inset) Thereafter for a few days irrigations of Dakin's solution are substituted In this way he states suppurating hæmatomata which are the principal causes of failure are obviated.

Lining the cavity with skin—All the principles of skin grafting have been invoked and the type of case which is suited to one or other of these procedures is the cavity which is well lined with granulations and has been treated by packing and plaster Once more, the type of grafting suited to one cavity is often contra-indicated in another It is not unusual to encounter cases following sequestrectomy, especially of the tibia, where wounds surrounded by scar tissue will not heal They are the seat of chronic infection, yet, as far as can be ascertained, the underlying bone is healthy Such cases respond particularly well to skin grafting In every case the wound must be rendered in a fit condition to receive a skin graft Whatever method of treatment has been employed, several days' irrigation with Dakin's solution or eusol is indicated, then follows three or four days' treatment with saline irrigation and packs Such treatment should cause the wound to become covered with small fresh granulations

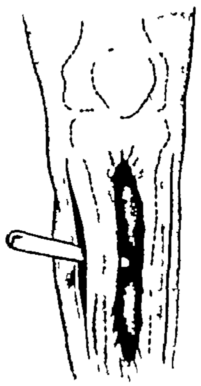


FIG 642

Whole thickness flaps are raised on either side of the cavity

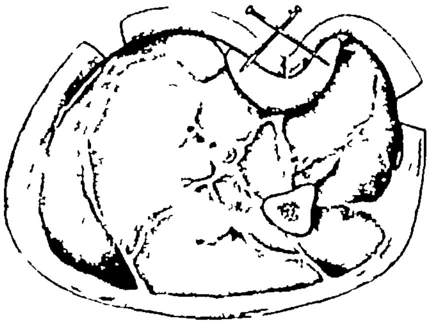


FIG 643

The grafts can be kept in contact with the bone cavity by tin tacks (*After Lord*)

FIG 644

Pedicle graft for lining a bone cavity (*After Kirschner*)

Thiersch grafts can be employed in selected cases They are applied on tulle gras (see p 181) which is held in place by a cast of dental wax moulded to fit the cavity just before the grafts are cut The dressing remains undisturbed for ten days Although at the first dressing the appearance is often disappointing, a further forty-eight hours will show that a number of the grafts have taken

Pinch grafts (see p 176) can also be employed

Sliding whole thickness skin grafts are admirable in deep troughs They have been used, particularly by French surgeons, with much success It is advisable to raise the flaps from the underlying soft parts on either side of the wound (Fig 642) and wait a week or ten days before fastening them into the bone cavity In order to keep the skin in contact with the walls of the cavity, French surgeons drill small holes in the bone and pass sutures through them

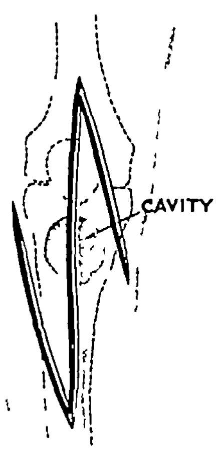


FIG 645

Another method of constructing pedicle grafts to fill a cavity in the upper end of the tibia (*After Lord*)

Lord employs tin tacks to fasten the graft in the bone The whole technique will be appreciated by reference to Figs 642 and 643

A pedicle graft is sometimes the best method of lining a cupped cavity Similar means of holding the graft in place can be employed Two types

of pedicle graft are shown in Figs 644 and 645 After a week or ten days during which time occasional irrigations are advisable the tacks are removed and a mould of dental wax is applied until the deep surface of the skin is attached firmly to the bone

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CHAPTER LXI

WOUNDS OF THE JOINTS OF THE UPPER EXTREMITY

THE SHOULDER-JOINT

SURGICAL ANATOMY

THE shoulder is a ball-and-socket joint with an extremely wide range of movement. The socket formed by the glenoid cavity being shallow, the articular surfaces are unadapted for stability, which depends mainly upon the tone of the surrounding muscles. To permit a wide range of movement the capsule is necessarily lax—so lax that it could accommodate a bone head twice the size of that of the humerus. There are four bursæ in relation to the shoulder-joint:—

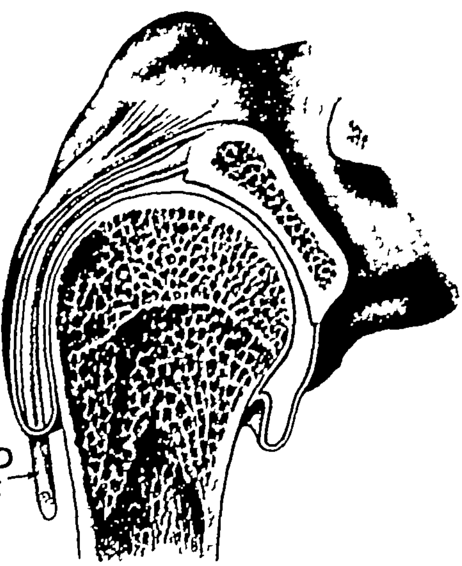

FIG. 646
Longitudinal section of the left shoulder-joint
(*After Sobotta.*)

1. **Subdeltoid and subacromial bursa** is one large cavity separating the deltoid and the under-surface of the acromion from the capsule of the joint, the tuberosities of the humerus and the upper part of the shaft respectively, from above, downwards. This bursa communicates with the shoulder-joint proper in 10 per cent. of cases.
2. **Subscapular bursa** lies between the subscapularis on the one hand and the neck of the scapula and the base of the coracoid process on the other.
3. **Infraspinatus bursa** separates the infraspinatus from the neck of the scapula.
4. **Synovial sheath of the biceps**.—The tendon of the long head of the biceps carries a tubular prolongation of the synovial membrane of the shoulder-joint into the canal in the humerus, in which it lies (Fig. 646). Pus in the joint may spread along this sheath.

Needling the joint.—The most accessible site for puncture is the anterior surface of the capsule close to the medial border of the deltoid.

Relations.—In close association with the shoulder-joint is the neurovascular bundle supplying the arm. Also related to the neck of the humerus is the circumflex (axillary) nerve supplying the deltoid (Fig. 647). It will be readily appreciated that wounds of the shoulder-joint are liable to implicate important nerves and blood vessels. An investigation has shown

that of 200 cases of wounds involving the shoulder joint sustained in the 1914 18 war only 5 per cent were unassociated with a complicating nerve lesion

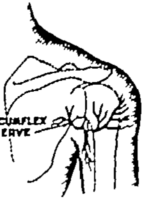

Fig 647

The posterior incision to expose the shoulder joint should be avoided because it endangers the nerve and blood supply to the deltoid muscle (After [illegible])

APPROACH TO THE SHOULDER-JOINT

One of the main objects of approaching the shoulder joint from its anterior aspect is to preserve the integrity of the circumflex nerve A small sandbag is placed behind the shoulder and the arm abducted slightly If the wound when it has been excised is not a suitable avenue of approach a fresh incision is recommended The incision extends from the coracoid process along the delto pectoral groove (Fig 648) The cephalic vein is defined and the interval between the deltoid and pectoralis major is sought On separating the muscles the anterior aspect of the joint is in view Some surgeons instead of seeking the delto pectoral groove split the deltoid muscle near its medial border This allows the cephalic vein to be carried to the medial side (Fig 649)

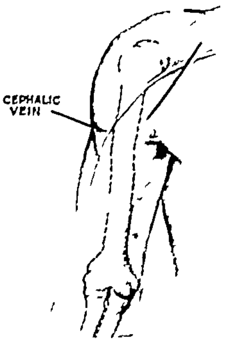

Fig 648

The anterior approach to the shoulder joint The line of the cephalic vein is [illegible]

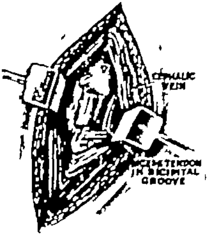

Fig 649

The shoulder joint exposed by splitting the medial fibres of the deltoid

Drainage can be effected through this route

Kocher's postero-superior approach may be useful occasionally It is designed to preserve the integrity of the circumflex nerve and at the same time give access to the posterior part of the joint The incision is shown in Fig 650 it commences over the acromio-clavicular joint and extends backwards over the acromion to end 2 in above the posterior

Fig 650

Kocher's postero-superior approach to the shoulder joint

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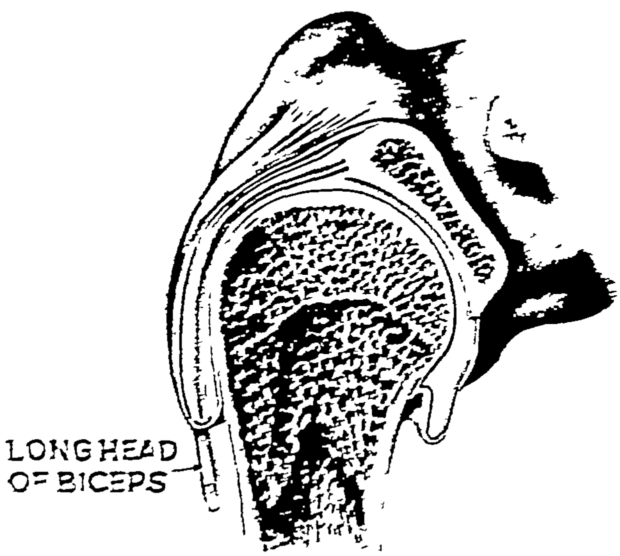

Fig. 646.
Longitudinal section of the left shoulder-joint.
([illegible])

1. **Subdeltoid and subacromial bursa** is one large cavity separating the deltoid and the under-surface of the acromion from the capsule of the joint, the tuberosities of the humerus and the upper part of the shaft respectively, from above, downwards. This bursa communicates with the shoulder-joint proper in 10 per cent. of cases.
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Relations—In close association with the shoulder-joint is the neuro-vascular bundle supplying the arm. Also related to the neck of the humerus is the circumflex (axillary) nerve supplying the deltoid (Fig. 647). It will be readily appreciated that wounds of the shoulder-joint are liable to implicate important nerves and blood vessels. An investigation has shown

After treatment—Active movement is then begun and is assisted by rehabilitating exercises If after such treatment movements are still restricted manipulation under anæsthesia is to be advocated This must be carried out with great care and it is always wiser to do too little than too much If necessary repeated gentle manipulations gradually extending the range of movement are preferable to a forced and extensive wrenching which is frequently followed by a serious reaction with so much pain and effusion that the movement already achieved by rehabilitation is lost

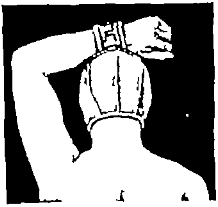

Fig 652
A method of maintaining the shoulder in abduction

During the early stages of after treatment it is often desirable to maintain full abduction A leather wrist *strap stitched to an aviator's* canvas helmet (Papurt) or a Rugby foot baller's skeleton cap (Forrester Brown) makes a most efficient apparatus for holding the shoulder in abduction (Fig 652)

LATE OPERATIONS TO REMEDY LOSS OF BONE SUBSTANCE

When there has been considerable loss of the head and neck of the humerus some kind of reparative operation may be considered Even after the wounds have been healed soundly for several months however the possibility of lighting up latent infection is considerable and apart from the immediate danger this will almost certainly jeopardize a favourable result For this reason provocative measures to produce such a flare up are recommended before a secondary operation is undertaken

There are two possible methods of reconstruction —

1 Operations aiming at a mobile shoulder joint and
2 Arthrodesis

If the former is to be attempted it is essential that there should be a well functioning deltoid muscle and an active un damaged long head of the biceps

Fig 653
Flail shoulder joint

During and after the 1914 18 war many mobilizing operations on the shoulder joint were performed The results were depressing producing either a flail power less arm (Fig 653) or one with very limited movement associated with a degree of pain incompatible with useful employment In the majority of cases the results were so unsatisfactory that when feasible arthrodesis was advised

Arthrodesis—Sound bony union of the scapulo humeral articulation in the optimum position of ab duction in front of the coronal plane ensures a most useful limb which provides power and stability al though its excursions are limited It enables the patient to earn his living As time goes on it is astonishing how much these patients can do in spite of the limited move ments Experience has shown that in the majority of cases a well ankylosed

axillary fold Sufficient muscle is cleared from the spine of the scapula to define the junction of the spine with the acromion The latter is detached from the spine by a chisel and hammer This enables the acromion, with the deltoid to be retracted laterally and exposes the upper, outer and posterior aspects of the joint covered by the spinati and teres minor muscles These muscles are detached from their insertions, giving free access to the capsule

TREATMENT OF THE BONY INJURY

Compound fractures involving the shoulder-joint may concern the glenoid cavity, the head of the humerus, or both

When the bony injury is confined to the glenoid cavity and the neck of the scapula the prognosis regarding function is exceptionally good Damaged portions of bone can be removed with much less trepidation than in the case of the head and neck of the humerus

On 1st June 1940, Private B was wounded by shrapnel in the posterior aspect of the right scapula The track of the projectile passed through the neck of the scapula, detaching two thirds of the articular surface of the glenoid No surgical treatment was carried out for three days On admission to hospital his temperature was 104° and the scapular muscles were grossly involved by sepsis, which required incision and excision, including the removal of the detached bone The arm was fixed in plaster of Paris in the optimum position, with drainage through the plaster The vast granulating surface rapidly healed except for some superficial ulceration in the scar, and active movements of the joint were begun a month from the time of operation Fig 651 demonstrates his range of movement six months after operation

FIG 651
Showing range of movement six months after an infected gunshot wound which necessitated removal of a piece of bone involving two-thirds of the glenoid cavity

When the head of the humerus is involved—The invariable effect of a projectile striking the head of the humerus is to break it into multiple fragments Loose fragments must be removed, preserving, if possible, the integrity of the tendon of the long head of the biceps Fragments still attached to the periosteum should be retained unless they are grossly contaminated

Immobilization—In all instances of compound fracture involving the shoulder-joint the aim should be to immobilize the arm completely in a position of abduction Experience in the present war has shown that this abduction can be best maintained by plaster of Paris The technique of applying the plaster is described on p 601 In the absence of an orthopædic table the immediate application of such a plaster is unsatisfactory (see Chapter LX) Plaster should not be applied immediately in cases where there is any doubt about the integrity of the vascular supply In cases of doubt or difficulty some form of aeroplane splint is used until a satisfactory shoulder spica can be substituted The arm should be kept abducted in plaster until healing has taken place

The bursæ around the articulation are unconnected with the joint

The subcutaneous olecranon bursa is situated between the integument and the posterior triangular surface of the olecranon process

The deep olecranon bursa is small and is situated in front of the upper surface of the olecranon. It separates the tendinous insertion of the triceps from the posterior ligament of the elbow joint.

There are also two small bursæ in relation to the insertion of the biceps tendon and two inconstant bursæ associated with the external and internal epicondyles respectively

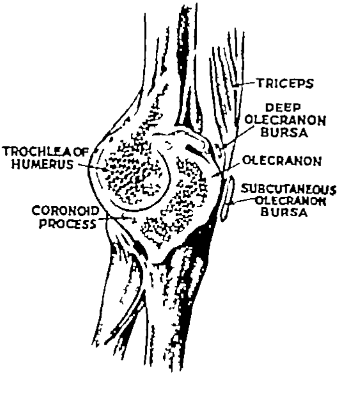

Fig 634

Longitudinal section through the right elbow joint from the ulnar side showing the synovial membrane and bursæ in relation to the joint (*After Spalteholz*)

Needling the joint—The needle is entered easily posteriorly between the head of the radius and the external epicondyle the joint being flexed to a right angle and the forearm semi pronated

Nerves in relation to the elbow - joint — The ulnar nerve bears an intimate relation to the joint lying immediately behind the internal epicondyle where it is easily palpated The posterior interosseous (deep radial) nerve passes round the neck of the radius and may be injured during operative procedures in this neighbourhood The median nerve is in less intimate relation to the capsule lying between the bicipital fascia (lacertus fibrosus) and the brachialis muscle the latter interposed between it and the joint It will therefore be appreciated that it is comparatively rare for the joint itself to be injured without the complication of a nerve lesion (Fig 635)

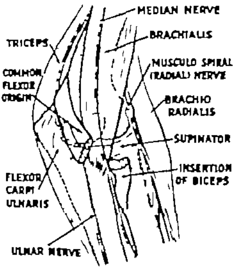

Fig. 635

Antero-medial composite diagram to demonstrate the relation of nerves to the elbow joint.

DRAINING THE JOINT

Free drainage is best provided by incisions on either side of the triceps tendon near its insertion, the forearm being maintained in the semiflexed position.

shoulder is a better working proposition than many of the best plastic results The following results of twenty-seven cases of penetrating wounds involving the shoulder-joint occurring during the 1914-18 war is eloquent in support of this contention None of these cases was associated at the time of the injury with nerve lesions

Bony ankylosis	21
Fibrous ankylosis	5
Flail joint .	1
	27

The disability assessment of those fixed by bony ankylosis depended upon the position of the arm and the function of the scapular musculature In the optimum position the disability rate was 40 per cent , and these men at some time or other in the twenty years have been employed on arduous work Of the patients with fibrous ankylosis all had varying degrees of painful movement, unfitting them for work In eight of these cases arthrodesis was carried out, after which they were comfortable and able to lead a useful economic life In the remaining six cases of fibrous union, arthrodesis would have been recommended but for repeated flares-up of latent infection

THE ELBOW-JOINT

SURGICAL ANATOMY

The elbow-joint is between the humerus above and the ulna and the radius below The superior radio-ulnar joint does not belong to the elbow-joint proper The latter articulation, which is between the upper end of the radius and the ulna, is a ball-and-socket joint dependent for its strength not on the bony conformation but on the strong orbicular ligament which encircles three-quarters of the head of the radius and is attached to the anterior and posterior edges of the lesser sigmoid cavity of the ulna

The movements of the elbow-joint permit of flexion and extension in a simple hinge manner, but owing to the obliquity of the trochlear surface this movement does not take place in the plane of the shaft of the humerus , when the forearm is completely extended it inclines outwards from the elbow at an angle of 170° This is called the " carrying angle " , it is frequently lost after fractures about the elbow

The best position for ankylosis will depend to a great extent upon the patient's occupation In general it is semiflexion, with the forearm midway between pronation and supination, so that by moving the shoulder the back of the thumb is brought to the mouth, which is the position of greatest use In the case of a clerk the position of the hand in writing, *i e* a few degrees of pronation, will be preferred for the right hand

The synovial membrane of the elbow-joint is extensive , it is reflected over the ligaments and forms a pouch between the lesser sigmoid cavity and the circumference of the head of the radius The synovial cavity (Fig 654) is most superficial at either side of the triceps tendon where swelling can be observed in cases of effusion into the joint

wounds after they have been excised being an unsuitable avenue of approach Ollier's bayonet-shaped incision (Fig 650) gives good access to the elbow joint proper and to the radio humeral and upper radio ulnar joints

FIG 650

Ollier's bayonet shaped incision for exposing the elbow joint.

Immobilization—The arm and forearm should be encased in plaster of Paris with the joint at a right angle and the hand in the supine position

LATER TREATMENT

When the acute inflammatory reaction has subsided the time has come to consider the eventual function of the joint There are two alternatives —

1 Mobility
2 Ankylosis

The choice is to some extent influenced by the patient's future occupation A mobile but unstable joint is of little economic value to a working man but a sound bony ankylosis in good position will provide a useful limb Conversely in many occupations a degree of mobility even if the thrust be weak is of more importance than a fixed stable joint Take the case of a professional violinist it is mobility of the elbow joint—not power—which is of paramount importance

Methods of securing mobility—When clinical examination supported by radiographs suggest that a fair range of movement should be attainable the following considerations must receive appropriate attention It should be noted carefully that joints which show seemingly devastating damage radiologically can develop a surprising range of movement Others demonstrating an apparently trifling bone lesion may fall far short of expectation It is therefore essential to consider the case carefully especially from the clinical aspect taking into consideration the patient's work before deciding on a particular course

Careful note should be taken of the range of active movement. The joint is then put through gentle passive movements until the point of limitation is reached. The nature of the resistance will be a very fair index as to whether one is up against a bony or fibrous obstruction. If it be fibrous the resistance will be resilient to some extent, and if the pressure is kept up it may cause pain. Should movement be restricted in all directions it is an indication of serious trouble in the joint itself and most likely there will be arthritic change If the movements of pronation and supination be free however the lesion may be sought outside the joint and a general arthritis of the articulation discounted When restriction is confined to flexion only or extension only one would expect a bony block in the one case and an anchoring adhesion or scar in the other The resilient type of resistance would be expected in such limitation of extension. Consulting the radiographs should be deferred until the clinical examination is completed, as in this instance radiography can be a very unreliable witness

CONTRACTED SCAR is a comparatively common cause of restriction of extension after wounds about the elbow joint have healed Physiotherapy will go some way towards the freeing of minor degrees of this condition but it is usually quicker and in most cases more permanent to excise the scar If normal skin margins cannot be approximated without tension a plastic flap from the abdominal wall gives satisfactory results

Fig 656
Thomas' collar and cuff

If the injury does not involve the articular surface, and the subsequent treatment does not require excision of the bone ends some degree of mobility may be expected, provided that adequate means are adopted to secure it Full flexion of the forearm in supination, preferably by the Thomas' collar and cuff method is the ideal starting position (Fig 656) As soon as the muscles have recovered their tone this is removed and function and gravity are both enlisted in the attainment of extension and pronation, which represent the normal position of the hand and forearm at rest As extension increases it is wise to re-apply the collar and cuff during the night in order to ensure the maintenance of full flexion and supination Failure to appreciate this necessity will lead to permanent loss of full movement

Fig 657
Flail elbow After excision of the lower end of the humerus

TREATMENT OF WOUNDS INVOLVING THE ELBOW-JOINT

Compound fractures involving the elbow-joint call for little special detailed consideration, the general principles concerned with the treatment of compound fractures due to projectiles hold good Loose fragments must be removed In certain cases where the joint is shattered and contaminated wide removal of bone is unavoidable In other instances an effort should be made to preserve pieces of bone attached to soft parts and reduce them Avoidable extensive resections are to be deplored, especially in the early stages of treatment, for so often a flail elbow (Fig 657) results The arm hangs as a useless appendage (Fig 658) and external splintage is needed to fix the articulation in a useful position Furthermore, operative intervention aimed at the relief of this instability is usually disappointing

Fig 658
Painless, unstable flail elbow

Approach to the elbow-joint—In the rare event of the wound or

THE WRIST-JOINT

SURGICAL ANATOMY

The wrist joint lies between the articular surfaces of the radius and the triangular cartilage (articular disc) proximally and the scaphoid (navicular) semilunar (lunate) and cuneiform (triquetrum) bones distally (Fig 660)

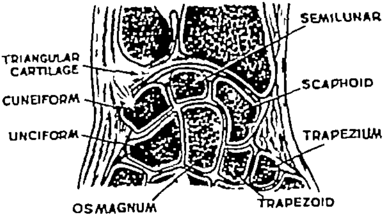

Fig 660

Section through wrist parallel to dorsal surface of the hand showing the synovial cavities. B.R. names of bones are given in the list below (After Sobotta)

Triangular cartilage	= discus articularis.	Semilunar	= os lunatum.
Cuneiform	= os triquetrum.	Scaphoid	= os scaphoideum
Unciform	= os hamatum	Trapezium	= os trapezium
Os magnum	= os capitatum.	Trapezoid	= os trapezoideum

There is no communication between the wrist joint and the joints of the carpus The distal radio ulnar articulation is also a separate entity this joint has a considerable synovial pocket extending upwards known as the recessus sacciformis On the other hand all the joints of the carpus communicate with one another with the exception of the piso-cuneiform joint

The best position for immobilization of the wrist joint is one of dorsi flexion in order to preserve the grasp and power of the hand This position may be retained either in a splint or in a plaster case but no matter which is used care should be taken to ensure that the metacarpo phalangeal and inter phalangeal joints are left quite free

SPECIAL CONSIDERATIONS IN WOUNDS INVOLVING THE WRIST-JOINT

As the wrist is not as a rule covered by clothing pieces of fabric are seldom carried in by projectiles Even when sepsis follows a compound fracture of this region experience has shown that the infection is comparatively mild Therefore if the case is seen early the prognosis should be excellent The particular points to bear in mind are that fractures involving the wrist joint frequently also involve the inferior radio-ulnar articulation and|or the carpal joints Conservation of injured carpal bones is poor surgery Tendons and their sheaths are also very prone to be injured in wounds about the wrist It is usually undesirable to suture tendons in cases where the

MANIPULATION—As in other joints after severe trauma, movements attained by the patient's active muscular contractions are permanent and sound, whereas surgical manipulation under anæsthesia, or forced passive movements by the masseuse, are frequently followed by local inflammatory reaction, which not only requires subsequent rest to alleviate it, but can so easily demoralize the patient On the other hand, there is a scope for manipulation of the elbow-joint where the bone lesion has not been extensive, and where adhesions are obviously limiting movement

When the wound has been involved in septic complications, before manipulating the joint it is wise to adopt provocative measures to reveal latent infection The minimal force must be applied and any feeling of bony block must dissuade the operator from continuing the manipulation On many occasions forearm bones, especially the olecranon process, have been fractured by injudicious manipulation In successful cases of joint manipulation tethering adhesions are broken down, and in order to reap the maximal benefit from this good fortune, thorough post-operative physiotherapy should be instituted at once In cases where full flexion and supination are attained the collar and cuff method (see p 684) is an admirable form of after-treatment

JOINT RESECTION—It has been pointed out that the majority of men prefer a soundly fixed bony ankylosis in the optimum position to a movable elbow with a comparatively weak arm On the other hand, there are callings where movement of the elbow is a prior consideration , also there are cases of fibrous ankylosis and painful arthritis in which excision of the joint is likely to improve the lot of the patient

If the ankylosis is limited to the radio-ulnar joint, excision of the head of the radius will often restore the power of pronation and supination

By excision of the elbow-joint is meant a carefully considered operation performed after all inflammation has subsided The approach is through a posterior incision, splitting the triceps, or Ollier's incision can be employed The ulnar nerve is dissected carefully and retracted out of harm's way, and the joint is entered By suitable dislocation the lower end of the humerus is exposed and that portion below a line joining the tips of the epicondyles is removed with a saw occasionally it is necessary to go a little higher After suitably clearing the head of the radius and ulna, section of these bones is carried out The ulna should be divided at a point that will just remove the articular surface of the coronoid process For the radius the resection should pass through its neck

It is remarkable how compensatory contraction of the biceps and triceps will overcome this large loss of continuity of bone, providing the operation is well executed and is followed by appropriate after-treatment

The arm is maintained in extension until healing takes place This is followed by fixation in full flexion and supination by the collar and cuff method The flexion is gradually reduced as muscle power develops

Throughout all stages of treatment of elbow lesions it is essential that the shoulder and the fingers should be kept freely moving, and the patient should be encouraged to put these joints through their full range of movement by his own voluntary effort

very troublesome but restoration of function in large degree may be confidently expected from Baldwin's operation

Baldwin's operation—In this procedure 1 to 1½ in. of bone and periosteum are resected from the lower end of the ulna, immediately above the styloid process through an incision on the subcutaneous border Following the operation the rotary movements which originally took place at the inferior radio-ulnar joint are now performed at the resulting ulnar pseudarthrosis.

INFECTIVE ARTHRITIS

Needling of the wrist-joint—The distal end of the radius is palpated and the needle is introduced between the tendon of the extensor indicis and extensor pollicis longus Arthrotomy is best performed through Ollier's first dorsal longitudinal incision (see Fig 661) If necessary through this incision by suitable retraction both rows of carpal bones can be displayed The differential diagnosis between infection of the ulnar bursa (p 720) and suppurative arthritis of the wrist is often difficult While Kanavel has shown that the wrist joint may become involved from infection of the ulnar bursa it is more usual that one or other of these conditions is present alone in the first instance but it may be a difficult matter to decide which In this connection a case quoted by Iselin is instructive

The patient was wounded in the anatomical snuff box by a piece of glass No treatment was undertaken for several days, when signs of abscess formation in the hand became manifest. J Quénu, the emergency surgeon, operated. There was no pus in the ulnar bursa Retracting the tendon sheaths aside he found the wrist-joint distended. He then made a dorsal incision and removed the semilunar bone in order to provide free drainage for the pus. The end result was excellent.

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joint is involved, one of the reasons being that the sutured tendons interfere with drainage It is better practice to reserve tendon suture until danger of infection has passed

TREATMENT OF RECENT WOUNDS

The wounds are excised and ragged tendons trimmed Loose fragments of the articular surface of the radius must be removed, but as much as possible of the lower end of the radius should be preserved, especially its styloid process When it comes to dealing with injured carpal bones, resection is indicated This should not necessarily be complete, but there must be due regard to lateral deformities, for instance, if it is necessary to remove the semilunar and scaphoid, the cuneiform should not be left When the fracture involves both the carpus and the metacarpus as little as possible should be done to the latter bones, especially if the tendons are intact, for fractures of the metacarpal bones generally heal well On the other hand, if the tendons of the corresponding finger are mutilated, a good method is to commence by amputating the finger with its damaged metacarpal bone, and to proceed to remove the fractured carpal bones through the ample incision which results The halves of the split hand can be united at once if the wound is clean, or left for secondary suture

FIG 661
Ollier's incisions for excision of the wrist joint

If the wound or wounds do not give adequate access to the wrist-joint and carpal bones, Ollier's incisions (Fig 661) for excision of the wrist may prove of value The principal incision follows the radial border of the extensor indicis After the tendon has been defined the incision is carried down to the periosteum The ulnar incision commences a little above the styloid process and runs down to 1 in above the lower end of the fifth metacarpal bone It is placed nearer the palmar than the dorsal aspect of that bone, so as to leave the tendon of the extensor carpi ulnaris in the dorsal flap of the wound This incision exposes the cuneiform and unciform In cases where it is thought feasible to suture the skin the joint can be immobilized in Jones' cock-up splint for a few days until it is ascertained that the danger of serious infection has passed In other circumstances the wound is packed lightly with vaseline gauze and a plaster cast applied with the wrist dorsiflexed

The treatment of late wounds involving the wrist-joint calls for no special mention, as the principles involved differ in no essential respect from those detailed in connection with other joints Limited removal of fractured carpal bones will aid in the establishment of free drainage which is so essential Ankylosis of the wrist-joint is compatible with excellent function provided that the wrist is in good functional position, and the tendons are not destroyed or the finger-joints stiff In many cases, however, there is associated ankylosis of the inferior radio-ulnar joint, leading to loss of the rotary movements of the forearm The disability resulting from this may be

Is primary amputation indicated?—In the great majority of cases the answer is definitely no. The mortality following amputation at or near the hip-joint in war time as estimated by various authorities ranges round the figures of 80 to 100 per cent. In all probability if a patient succumbs without amputation his death would be hastened by the radical operation. In advising against amputation full consideration has been given to modern resuscitative measures. In the exceptional case where gangrene is threatened or hæmorrhage cannot be controlled by other means there is no option and the risk must be faced. In selected cases the sleeve amputation (see Chapter LXVIII) is a life saving measure. It was designed by the writer in 1916 to obviate disarticulation of the hip in cases of bad surgical risk.

Primary closed plaster technique is contraindicated.—Whatever may be the merits or demerits of this technique in other regions it should not be employed in cases with severe wounds involving and surrounding the hip joint. A number of such cases were seen during the past year injured extensively on board ship by mines, torpedoes, bombs and shells. Plaster fixation in the majority proved an embarrassment to those responsible for the subsequent treatment, and it was often the cause of a poor final result. The necessary extension was not provided and the removal and replacement of a plaster encasing the entire limb and pelvis was found to be by no means a minor procedure. Jones abduction frame as set out in Chapter LVII is recommended as a substitute for plaster. Plaster may be applied when the danger period has passed, but it is better to conduct the entire treatment on the abduction frame. The immobilization is satisfactory. The dressings should be infrequent.

Because of bone infection or proximity to and consequent infection from the anus such wounds are seldom suitable for secondary suture. On the other hand large gaping deep lacerations of the buttock when the time comes lend themselves to corsettage. In this connection the following case is relevant:—

A stoker was seated on the lavatory when his ship struck a mine. The broken crockery inflicted a large wound of the right buttock which involved the anus. The coccyx and sacrum were fractured. By the time he reached hospital six days later the wound was grossly infected. By immobilization on a modified abduction frame and suitable treatment, which included a colostomy, a comparatively healthy granulating wound was obtained. Corsettage proved a great help in expediting healing. Secondary suture was partially successful.

OPERATIONS UPON THE HIP-JOINT

Major operations upon the hip-joint are seldom indicated in war wounds. The question resolves itself largely into methods of providing free drainage in the case of potential or actual suppuration within the joint. If severe comminution of the head and neck is present with infection and there is tracking of pus and the conversion of bone fragments into sequestra, the whole head and a portion of the neck of the femur should be excised. Unlike the knee-joint, the synovia of which is so large and superficial, repeated aspiration of the hip-joint for therapeutic purposes is sometimes impracticable. By the time the need for aspiration of the hip-joint enters the picture the joint will usually require surgical drainage. The advantages of the timely entry of a hollow needle into this deep-seated joint cavity and the demonstration of pus is a matter for frequent consideration.

CHAPTER LXII

WOUNDS INVOLVING THE HIP-JOINT

A WOUND which involves the hip-joint from any aspect (Figs 662 and 663) is likely to be devastating Large vessels and nerves, more particularly the femoral vessels and the sciatic nerve, often are implicated and, in addition, the femur and the pelvic bones may be

Fig 662
Anterior aspect of the hip-joint

Fig 663
Posterior aspect of the hip-joint (L H Taylor)

shattered A study of statistics, ranging from the war in the Crimea to the Spanish civil war, gives grim and gloomy information Most of the complicated cases died in transit to hospital Wounds of the hip-joint present problems which need special consideration

downwards and inwards for 3½ in The sartorius and rectus femoris muscles are retracted to the inner side the tensor fasciæ femoris and gluteus medius and minimus to the outer side of the wound Without division of any muscles vessels or nerves of importance the anterior part of the capsule of the joint can be reached in the interval between the muscles mentioned. The neck of the femur is divided with an Adams saw or broad chisel while the head of the bone is still *in situ* After the division of the bone the head is levered out of the acetabulum with a strong broad gouge Drainage can be established by a counter-opening behind and in making this opening the author's thimble may be found of use (Fig 665)

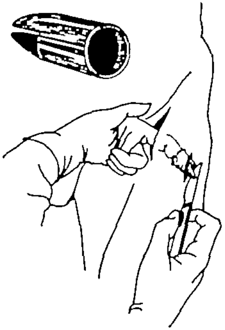

FIG 665

Approaches to the hip-joint. Making counter-drainage with the aid of a thimble *Inset*—Author's thimble to protect the finger

Lateral approach—This method was employed by J B Murphy for arthroplasty of the hip It gives an excellent exposure The patient lies on his side A curved incision commences at the anterior superior spine passes downwards below the top of the great trochanter and ends in the region of the posterior superior iliac spine The aponeurosis of the gluteus maximus is incised vertically and retracted backwards The great trochanter is divided either obliquely from below upwards with a chisel or in the reverse direction with a Gigli's saw 1 in below its upper margin The detached portion is retracted upwards with its attached muscles (gluteus medius gluteus minimus) (Fig 666) The other muscles are divided or separated with a periosteal elevator The joint capsule and margin of the acetabulum are now exposed The capsule is opened vertically and, when indicated the head of the femur is dislocated from the acetabulum by adduction and internal rotation of the thigh In civil surgery when the operation is completed the detached portion of trochanter is usually fixed in position by a peg or nail This method should not be attempted in the presence of infection It is best to approximate the parts with a few interrupted catgut stitches and not to attempt anything more

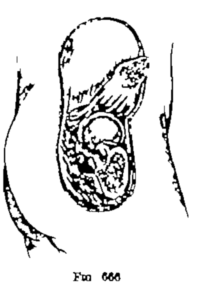

FIG 666

Lateral approach to the hip-joint. The tip of the trochanter and gluteus medius and minimus muscles are displaced upwards. The tendons of the obturator internus, gemelli and pyriformis have been divided. (*After J B Murphy.*)

Posterior approach—This is probably the best approach for the purpose of drainage It was advocated by Kocher The patient lies prone The incision begins at the base of the posterior surface of the great trochanter

Needling the joint—The puncture may be made about $2\frac{1}{2}$ in below the anterior superior iliac spine, between the sartorius and the tensor fasciæ femoris A large bore needle is pushed upwards, inwards and backwards beneath the tendon of the rectus femoris It passes through the capsule just above the anterior intertrochanteric line It will be remembered that the tensor fasciæ femoris, as it descends, diverges from and makes an angle with the sartorius, and in this angle the rectus may be felt as it covers the capsule of the hip-joint Hamilton Bailey suggests locating the femoral artery with a finger of the left hand just below Poupart's ligament and driving the needle external to this point with an upward tilt towards the head of the femur He points out that it may be necessary to manipulate the needle several times before a satisfactory entry is assured

SURGICAL APPROACH TO THE HIP-JOINT

In the past as many as eighteen different methods of exposing the hip-joint have been described The joint may be reached by an anterior

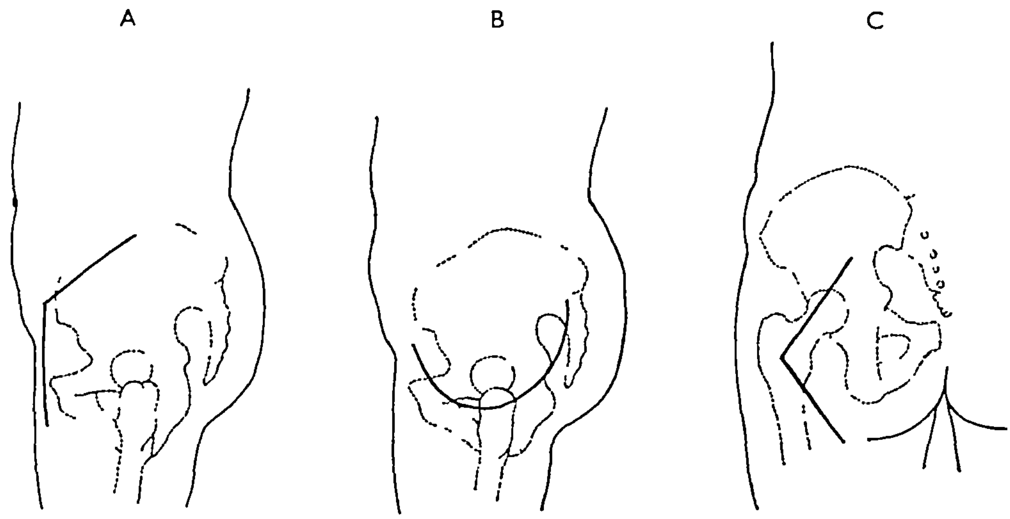

Fig 664
Approaches to the hip-joint
A, Anterior approach B, Lateral approach C, Posterior approach (*After Allison*)

approach, a lateral approach or a posterior approach (Fig 664) The choice will depend on the extent and position of the wound

Anterior approach—The patient is rolled partially over to the opposite side, with a long sandbag supporting his back

Modified Smith-Peterson incision—A curved incision passes along the crest of the ilium from the anterior superior spine to the middle of the crest The incision is prolonged vertically downwards from the anterior superior spine for 4 or 5 in The horizontal portion over the crest is deepened to the bone The origin of the gluteus medius is cut and the side of the ilium stripped of periosteum and muscles with a periosteal elevator This portion of the wound is then packed with gauze The lower vertical portion of the wound is deepened in the interval between the sartorius in front and the tensor fasciæ femoris behind With the introduction of retractors the capsule of the hip-joint comes into view The capsule is opened freely and the anterior portion of the head of the femur exposed Flexion and rotation of the thigh will deliver the head

When time is a factor the following less extensive operation sometimes will suffice A straight incision is made from the anterior superior spine

downwards and inwards for 3½ in The sartorius and rectus femoris muscles are retracted to the inner side the tensor fasciæ femoris and gluteus medius and minimus to the outer side of the wound Without division of any muscles vessels or nerves of importance the anterior part of the capsule of the joint can be reached in the interval between the muscles mentioned The neck of the femur is divided with an Adams saw or broad chisel, while the head of the bone is still *in situ* After the division of the bone the head is levered out of the acetabulum with a strong broad gouge Drainage can be established by a counter-opening behind and in making this opening the author's thimble may be found of use (Fig 665)

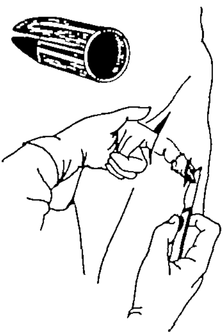

Fig 665

Approaches to the hip-joint Making counter-drainage with the aid of a thimble *Inset*—Author's thimble to protect the finger

Lateral approach—This method was employed by J B Murphy for arthroplasty of the hip It gives an excellent exposure The patient lies on his side A curved incision commences at the anterior superior spine passes downwards below the top of the great trochanter and ends in the region of the posterior superior iliac spine The aponeurosis of the gluteus maximus is incised vertically and retracted backwards The great trochanter is divided either obliquely from below upwards with a chisel, or in the reverse direction with a Gigli's saw 1 in below its upper margin The detached portion is retracted upwards with its attached muscles (gluteus medius gluteus minimus) (Fig 666) The other muscles are divided or separated with a periosteal elevator The joint capsule and margin of the acetabulum are now exposed The capsule is opened vertically and when indicated, the head of the femur is dislocated from the acetabulum by adduction and internal rotation of the thigh In civil surgery when the operation is completed the detached portion of trochanter is usually fixed in position by a peg or nail This method should not be attempted in the presence of infection. It is best to approximate the parts with a few interrupted catgut stitches and not to attempt anything more

Fig 666

Lateral approach to the hip-joint The tip of the trochanter and gluteus medius and minimus muscles are displaced upwards. The tendons of the obturator internus, gemelli and pyriformis have been divided. (*After J B Murphy*)

Posterior approach—This is probably the best approach for the purpose of drainage It was advocated by Kocher The patient lies prone The incision begins at the base of the posterior surface of the great trochanter

From this point it is carried successively in two directions (see Fig 664, C), firstly, in a direction upwards and backwards towards the spine, following the course of the fibres of the gluteus maximus, secondly, downwards and backwards towards the outer extremity of the fold of the nates The entire incision should measure about 6 in in length The outer surface of the trochanter is exposed by the division of the fascia of the gluteus maximus muscle The attachment of the gluteus medius then becomes evident This is also divided The fibres of the gluteus maximus are separated and the muscle is displaced upwards to bring the tendon of the pyriformis into view The upper fibres of the gluteus maximus or the entire muscle, together with the gluteus medius, being retracted upwards and forwards, the pyriformis is displaced downwards This exposes the posterior part of the capsule of the joint While the assistant rotates the leg, the exact position of the articulation can be ascertained The attachment of the gluteus medius and gluteus minimus muscles, together with the periosteum, are separated from behind forwards from the trochanter Afterwards the insertion of the external rotators of the thigh, viz , the pyriformis, obturator internus, the gemelli and obturator externus, are separated from the inner aspect of the great trochanter If the thigh is rotated inwards by the assistant during the division of the tendons, the posterior aspect of the head and the neck of the femur is now clearly localized and the joint is opened by division of the capsule The ligamentum teres is divided by cutting on the head of the bone, the thigh being at the time in a position of strong adduction, flexion and medial rotation The head of the femur is dislocated out of the acetabulum and removed with as much of the neck as is found necessary

FINAL RESULTS AND LATE TREATMENT OF INJURIES ABOUT THE HIP-JOINT

In the early days of treatment the surgeon must bear in mind the future and his ultimate aim It is best to treat the case in slight abduction and extension as if sound bony ankylosis was to be expected Unfortunately, such a result is the exception and not the rule It is more common to find an unsound ankylosis, and if abduction and extension have not been maintained over a long period, the familiar deformities of flexion, adduction and internal rotation supervene and present a new problem

To correct flexion and adduction in the absence of sound ankylosis—The patient is anæsthetized The uninjured thigh is bent on the abdomen to obliterate lordosis and the flexed injured thigh gently manipulated into the extended position Adduction is corrected while both legs are in the extended position The patient is then treated on the abduction frame for a fortnight, and subsequently fixed in the corrected position in a plaster spica which includes the foot and the opposite thigh

If much force is required to secure correction by manipulation, it is better to abandon the attempt, as the neck of the femur is easily fractured Division of the adductors subcutaneously, and gradual correction by fixation on the frame is then the treatment of choice In some cases pain and stiffness persist after correction of deformity This is an indication for further rest and immobilization in plaster With patience and sufficient rest, limited movements reappear and then further manipulation may be tried

To correct flexion and adduction in the presence of sound ankylosis—When the limb is in a position of slight flexion and there is no adduction function is but little interfered with by any form of ankylosis No treatment is necessary Shortening is corrected by a raised boot On the other hand a position of flexion and adduction may produce considerable disability If there is sound ankylosis it is obvious some form of operative treatment will be necessary for the correction of these deformities

OSTEOTOMY—The aim of operation is to obtain slight abduction and to bring the limb into a position of slight flexion at the hip (25) with the patella pointing straight forwards Slight abduction will correct slight shortening but the production of wide abduction to correct marked shortening is not desirable Considerable shortening must be compensated by a raised boot The best operation is an oblique incision of the femur through the great trochanter (Fig 667) The line of division is as a rule parallel to Poupart s ligament Osteotomy through the femoral neck has been discarded owing to the danger of non union

FIG 667
Transtrochanteric osteotomy

Open transtrochanteric osteotomy—The patient lies on the sound side A transverse incision is made about ¾ in below the tip of the great trochanter With an electric saw or broad chisel the bone is divided downwards and inwards Usually the bone will fracture easily when the division is carried deeply The densest bone is however on the inner side and the chisel may be required until division is complete Radiography will indicate when a wedge-shaped osteotomy is desirable It is performed in the same manner except that the saw or chisel fashions a wedge in the bone

Subcutaneous transtrochanteric osteotomy is a satisfactory operation A long and narrow bladed knife is inserted through a very small incision just below the tip of the great trochanter The knife is then passed, in contact with the bone in a direction parallel to Poupart s ligament The knife is left *in situ* to act as a guide for an Adams or Jones osteotomy saw and is withdrawn when the latter instrument is in position The bone is sawn through the greater part of its depth and then fractured The adductor muscles may require subcutaneous division

FLAIL HIP-JOINT

This condition results from extensive loss of bone either at the time the wound is inflicted or by subsequent operation Attempts at weight-bearing are followed by a telescopic action of the thigh on the side of the pelvis

The treatment is conservative A jointed caliper splint is worn for a year In a proportion of cases the stability of the hip has so improved by this time that the splint may be discarded. In some cases the splint cannot be tolerated and in these the best operation is to slide a longitudinal section of the shaft of the femur upwards into a prepared acetabulum This massive slide graft must have a contact of at least 3 in with the shaft of the femur below It can be secured by vitallium screws or by

From this point it is carried successively in two directions (see Fig 664, C), firstly, in a direction upwards and backwards towards the spine, following the course of the fibres of the gluteus maximus, secondly, downwards and backwards towards the outer extremity of the fold of the nates The entire incision should measure about 6 in in length The outer surface of the trochanter is exposed by the division of the fascia of the gluteus maximus muscle The attachment of the gluteus medius then becomes evident This is also divided The fibres of the gluteus maximus are separated and the muscle is displaced upwards to bring the tendon of the pyriformis into view The upper fibres of the gluteus maximus or the entire muscle, together with the gluteus medius, being retracted upwards and forwards, the pyriformis is displaced downwards This exposes the posterior part of the capsule of the joint While the assistant rotates the leg, the exact position of the articulation can be ascertained The attachment of the gluteus medius and gluteus minimus muscles, together with the periosteum, are separated from behind forwards from the trochanter Afterwards the insertion of the external rotators of the thigh, viz, the pyriformis, obturator internus, the gemelli and obturator externus, are separated from the inner aspect of the great trochanter If the thigh is rotated inwards by the assistant during the division of the tendons, the posterior aspect of the head and the neck of the femur is now clearly localized and the joint is opened by division of the capsule The ligamentum teres is divided by cutting on the head of the bone, the thigh being at the time in a position of strong adduction, flexion and medial rotation The head of the femur is dislocated out of the acetabulum and removed with as much of the neck as is found necessary

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CHAPTER LXIII

WOUNDS OF THE KNEE-JOINT

THE introduction of foreign material into so large and complex a joint as the knee is always a matter for grave concern If the injury is merely a penetration of the joint capsule without serious damage to bone or cartilage it may eventually have little ill-effect providing that it is dealt with early and efficiently Delay or inefficiency usually results in severe suppurative arthritis with loss of limb or even of life

THE SYNOVIAL CAVITY OF THE KNEE-JOINT

Before proceeding to a consideration of the details of treatment it is advisable to recall the anatomy of the synovial cavity of the joint (Fig 669) The main space is anterior lying above and to the sides of the patella There are however a pair of large posterior pouches in addition These extending posterior to and to some extent between the femoral condyles are separated by the invagination of the synovial membrane covering the cruciate ligaments lying in the middle of the joint

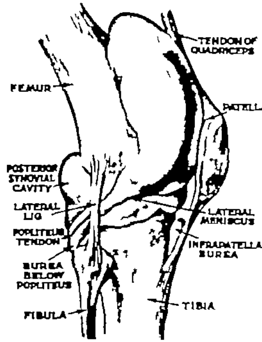

FIG. 669
The synovial cavity of the knee-joint distended.
(*After Spalteholz.*)

METHOD OF DRAINING THE JOINT

When drainage of the anterior space is required it is provided best by incisions respectively half an inch lateral and medial to the patella (Fig 670) and so placed that two-thirds of each incision lies above the level of the upper border of that bone Occasionally infection extends into the posterior pouches which then must be drained also The best method of effecting posterior drainage is to pass a director backwards from the anterior incisions On the medial side the director is passed between the medial femoral condyle and the tibial collateral ligament above its attachment to the medial meniscus and an incision made over the point of the instrument The procedure is similar on the lateral side but in this instance the

two or three encircling strips of ribbon catgut passed round the shaft with the aid of a large aneurism needle or other guide The limb is fixed on an abduction frame until the stitches are removed and then firmly secured in plaster for three months A weight-bearing caliper is worn for a further three to six months

A more simple plan is to take a large graft from the tibia, thick enough to be a tight fit for the medullary cavity of the femoral shaft and about 9 in long This peg graft is inserted into the medullary cavity, leaving the required length projecting towards the acetabulum (Fig 668)

FIG 668

Intramedullary peg graft to provide support in cases of flail hip The projecting portion increases in girth with weight-bearing The intermedullary portion absorbs and disappears

For the first three months X-ray pictures may give the impression that absorption of the graft is taking place This appearance is deceptive It merely indicates that the demolishing powers of the osteoclasts are more apparent than the reproducing capacity of the osteoblasts

Later this appearance is reversed, and as function is resumed with the protection of a caliper, Wolff's law comes into operation The graft increases in size and density until it reaches a diameter nearly equal to that of the femoral shaft

Rigid fixation for the first three months is essential and subsequent weight-bearing must be very gradual

Sometimes a surprisingly useful joint follows severe injury and loss of bone Such cases were seen at Blackrock Military Orthopædic Hospital, Dublin, during and after the 1914-18 war In some, there had been drainage for from two to three years The final result often gave a wide range of active mobility, and weight-bearing was not interfered with Shortening was corrected by a raised boot The practical lesson from such late results is that extensive removal of bone need not be feared when such removal is the only alternative to amputation

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driven into the articular surface of the femur Immediate operation was carried out in the manner detailed below Subsequent progress was excellent and a full range of movement from 45° to 180° resulted

As a parallel in civil life to the suppurating joints of warfare there are the cases in which the joint becomes infected after penetration of a foreign body and also those which become infected as a result of osteomyelitis of the upper end of the tibia the lower end of the femur or the patella

Case II illustrates the result obtained in a case of suppurative arthritis secondary to acute osteomyelitis of the lower end of the femur The patient was a youth of fourteen years and the joint was drained by two anterior incisions immediately after it was known to be infected The synovial incisions were left open with corrugated rubber drainage extending down

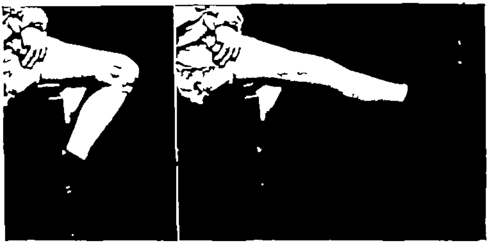

FIG 673

Case II. Suppurative arthritis following acute osteomyelitis of the lower end of the femur Immediate drainage resulted in the above complete range of movement—from 60° to 180°

to but not into the joint cavity At the end of three days there was little or no discharge and the wounds were allowed to heal The range of movement which resulted is almost complete—from 60° to 180° (Fig 673)

In all cases of wounds of the knee joint the joint must be given absolute rest throughout the whole of the immediate after treatment and well into the period of convalescence

Much was said and written during and after the war of 1914-18 concerning the advantages of early movement in wounds of the knee joint. It was argued that the institution of early movement prevented ankylosis, and was more likely to result in a movable joint than was complete rest It is true that in a small proportion of those cases subjected to early movement ankylosis was avoided, and some of these regained a considerable degree of flexion and extension, but experience has shown that in both civil and military work far better results have followed treatment by complete rest until convalescence is well established. The majority of British surgeons concur with this view

Proof of the efficacy of this treatment is afforded by Case II cited above It demonstrates that even if the joint is full of pus with adequate drainage and rest full recovery of movement is possible Examples of this kind can be provided by every orthopædic surgeon of experience

collateral ligament is not attached to the meniscus and the director passes freely backwards, lateral to the popliteus tendon (Fig 671)

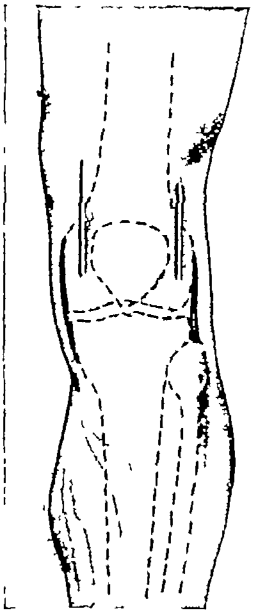

Fig 670
Incisions for draining the anterior synovial space As a rule it is best that two-thirds of the incision should lie above the upper border of the patella

MODERN CONCEPTION OF TREATMENT

The problems of wounds of the knee-joint in war are precisely those which confront us in the accidental wounds of civil life The three cases cited as typical examples in the present contribution are all of recent civilian origin, but they serve to demonstrate technique and results better than would reference to cases of the 1914-18 campaign, seeing that our methods of treatment have changed in so many respects since that time

On the one hand, there are those cases where a foreign body, usually a fragment of glass or a small pointed object such as a nail or a splinter of wood, penetrates into the joint accidentally If these circumstances are recognized quickly and early operation performed, the result is usually extremely good On the other hand, if they are not recognized until signs of local inflammation, coupled with pain and pyrexia, produce alarm, a much more serious problem presents itself With proper treatment it is still possible to attain a good result, but this is by no means always feasible, for the joint may have become entirely disorganized Ankylosis and, if the septic process continues to advance, the prospect of amputation, enters the picture

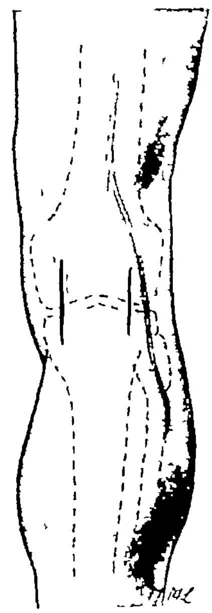

Fig 671
Incisions for draining the posterior synovial pouches In each case a director is passed from the corresponding anterior incision and the joint is entered by cutting on to the probe extremity of the instrument

Case I A youth fell on his left knee and experienced a sharp stabbing pain A small wound was found in front of the joint in its proximal and medial quadrant, and although no foreign body could be seen, it was surmised that something had penetrated the cavity In every wound of the knee-joint lateral and anteroposterior radiographs are essential In this case the X-rays revealed a pen-nib (Fig 672) lying entirely inside the joint with its point

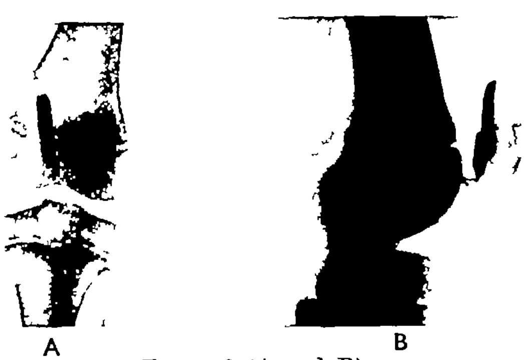

Fig 672 (A and B)
Foreign body (a pen nib) in the knee joint

As in type 1 the limb is immobilized on a Thomas splint After such treatment many cases run an uneventful course

Should local or constitutional evidence of sepsis follow a hollow needle is introduced into the joint and the fluid aspirated is sent for bacteriological examination When infection is present but is obviously mild it is wise to wait twenty four hours and by re aspiration to obtain a further specimen Chemotherapy is of uncertain value in these cases but drugs of the sulphonamide group are worth a trial particularly in the presence of a hæmolytic streptococcal infection

In cases where the joint contents become frankly infected the wounds must be reopened forthwith and if thought advisable the cavity flushed gently with normal saline A small drain is placed in each wound extending down to but not through the synovial layer If all goes well the drains are removed in twenty four hours

Certain writers on this subject have used such phrases as efficient sterilization of the joint cavity by irrigation Short of irrigating a joint with a completely destructive fluid such as pure carbolic acid or some of the fearsome mixtures of phenol camphor and alcohol which found employment during the war of 1914 18 it is quite absurd to think that a joint once infected can be *sterilized* by irrigation We know that such joints can become *clean* again The truth is that the synovial membrane and its secretion deal with the bacteria and that if the joint is efficiently drained for a period which varies with the severity and duration of the infection many joints make a full functional recovery without any sort of attempt at irrigation Moreover irrigation can be a danger in that it may carry infection to the outlying pockets of the joint For this reason the method of forced distension of the joint suggested by Cotton finds little support

If an urge to irrigate the joint is felt a fluid which can cause the least harm viz normal saline should be used at the lowest pressure possible Chemicals of all kinds in weak solution as so often recommended have no advantage whatever over saline and in stronger solution they are irritants and therefore a positive danger

Having inspected the interior of the joint and having wiped out gently any coagulated lymph or blood clot with a moistened swab the synovial wounds are left open The skin edges are approximated lightly leaving a strip of vaselined gauze down to each of the unsutured synovial wounds

In the war of 1914-18 it was suggested that infected knee-joints should be excised whilst still frankly septic. This procedure was carried out in a number of cases with disastrous results. Pus tracked down the calf and up the thigh and those patients who survived all came to amputation

Following the treatment recommended here the infection sometimes subsides rapidly and the wounds heal If such a fortunate result occurs the joint is likely to recover with a considerable range of movement *but no attempt should be made to force such movement* The limb must be kept at rest on the splint until all wounds have been healed for ten days Then a little active movement may be allowed with the knee resting over a small sandbag The following is an illustrative case —

On 6th June 1940 a youth whilst bathing in a stream received a cut over the medial side of the right knee It bled a little and was covered by a handkerchief He walked home and a fresh dressing was applied Six

MANAGEMENT

In all penetrating wounds of the knee-joint prophylactic anti-tetanic and anti-gas-gangrene sera should be given For detailed consideration it is convenient to divide wounds of the knee-joint into four types —

Type 1. Small wounds of entrance and exit, with a minimal degree of laceration—Radiographs are essential In the absence of a foreign body the joint is immobilized on a Thomas' splint, as set out in Chapter LVI The patient's temperature and local condition are observed twice daily Occasionally small pieces of projectile moving at a high velocity may pass in and out, causing hardly any damage to the synovial membrane If no local or constitutional reaction follows, the joint will probably settle down in a day or two and the wounds will heal If, however, an effusion and signs of infection appear, the joint cavity must be explored with a medium-bore hollow needle on the lateral side and the contents aspirated The fluid will show a varying amount of turbidity, or even actual pus

When turbid fluid is aspirated a Gram-stained film will give some indication of the severity of the infective process Few organisms with a high proportion of mononuclear cells suggest a mildly infected fluid The presence of many organisms and polymorphonuclear cells is a more serious portent, and the streptococcus hæmolyticus is the organism most to be feared

An improvement in the general condition may follow aspiration, in which case further aspiration should be carried out on the following day In some instances, after two or three such aspirations the inflammatory process resolves

Should the condition become worse—and daily aspiration and observation of the patient's general condition are sure guides—drainage of the joint is essential, and it is carried out as detailed on p 697 After ten days, providing the general and local conditions are entirely satisfactory, the splint may be removed and a little active movement permitted Cases which respond to repeated aspiration must remain splinted until at least ten days after the last aspiration

Type 2 Lacerated wounds are present—Again X-ray examination followed by immediate operation is the proper course A tourniquet is applied to the thigh The skin and wound edges are cleansed with ether and the damaged skin edges and subcutaneous tissues excised with meticulous care, making sure that every piece of torn, frayed or bruised tissue is cut away cleanly Attention is now directed to the torn edges of the synovial membrane A most important step in the surgical procedure is that *the synovia must be attended to with a fresh knife and forceps* , indeed, all instruments used in the preliminary stages of the operation are discarded The wounds in the synovia are excised and the interior of the joint examined Bearing in mind the radiographs, foreign bodies are sought, but it is just as necessary to remove non-opaque foreign matter, including any blood and blood-clot The latter is wiped away with gauze swabs moistened with saline

If the case is seen within six hours after the infliction of the injury the wounds can be closed in three layers with interrupted catgut sutures

cases Sepsis may gain the upper hand and the joint become violently infected If this occurs ankylosis will surely follow Spread of sepsis to the posterior synovial pockets will make it necessary to provide posterior drainage as described on p 697

Type 3 Lacerated wound with fracture—A foreign body may or may not be present When the radiograph shows a limited degree of fracture of one or more of the bones but the major part of the articular surfaces intact the treatment should be exactly as that detailed for type 2 with the addition that all loose fragments of bone and cartilage must be removed When the patella is fractured it is often a good practice to excise it

Type 4 Lacerated wound with more extensive bony damage—Usually the wound is larger than in the foregoing groups and there may be loss of considerable portions of bone and articular cartilage indeed these may be so extensive that there is no chance of a movable joint resulting

Such cases are comparable to compound fractures with a large wound They are best treated by complete removal of all damaged tissues laying open all the injured surfaces and providing a well-exposed area with no pockets If the patella is shattered it should be removed completely

The resulting large cavity is packed lightly with vaselined gauze The entire limb is then encased in a plaster spica If the general condition of the patient remains good the plaster may be left undisturbed for two weeks when it should be bi valved and the wound inspected A new dressing is applied and the plaster replaced Later as the wound granulates changes of plaster will be required at intervals of a few weeks The aim in these cases is to produce firm ankylosis in full extension

Again there is the possibility which increases with every hour that elapses between wounding and efficient surgical treatment that serious infection will supervene Should this occur or secondary hæmorrhage threaten timely amputation through the thigh can never be an occasion for regret

* * * * * * * *

Summarizing It can be stated that if wounds of the knee-joint receive early and adequate operative treatment, on the whole the results are excellent To obtain these results first-aid posts where not actually part of the general hospital service must be instructed to send all wounds in the neighbourhood of joints to their associated hospitals at once

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Fig 674
Case III Suppurative arthritis following a wound Granulating and almost healed wound twenty days after joint was drained On the day active movement was initiated

days later he began to sleep badly and the joint became painful It was found to be swollen and the temperature was raised His doctor was summoned, and found the lad feverish and with an obviously septic joint He advised his removal to hospital

On admission, 13th June, the temperature was 102° F The knee-joint was distended and held at an angle of 135°, any movement was painful There was a dirty wound about 1 in long, with a little serous discharge on the medial side of the knee A blood count showed 17,500 white cells

Operation—The wound was excised and the joint found to contain pus A specimen was sent for bacteriological examination and was reported "staphylococcus aureus" A second incision was made on the lateral aspect of the joint (Fig 674), and the interior was cleansed of several large flakes of lymph clot, using a moistened swab A small drain was placed down to the synovial layer on each side and the synovial wounds left unsutured The limb was then placed with the knee fully extended on a Thomas' splint

The pyrexia abated and by the fourth day became normal, and remained so Ten days later both operation wounds were healing well and there was no discharge Two days after this, 26th June, the limb was removed from the splint and a small amount of flexion and extension allowed over a sandbag On 7th July, as shown in Fig 675, the range of movement had increased from 135° to 180° This knee will, in all probability, recover an equally good range to that depicted in Fig 673

Such an excellent result as this cannot be expected in all, or even a high percentage of

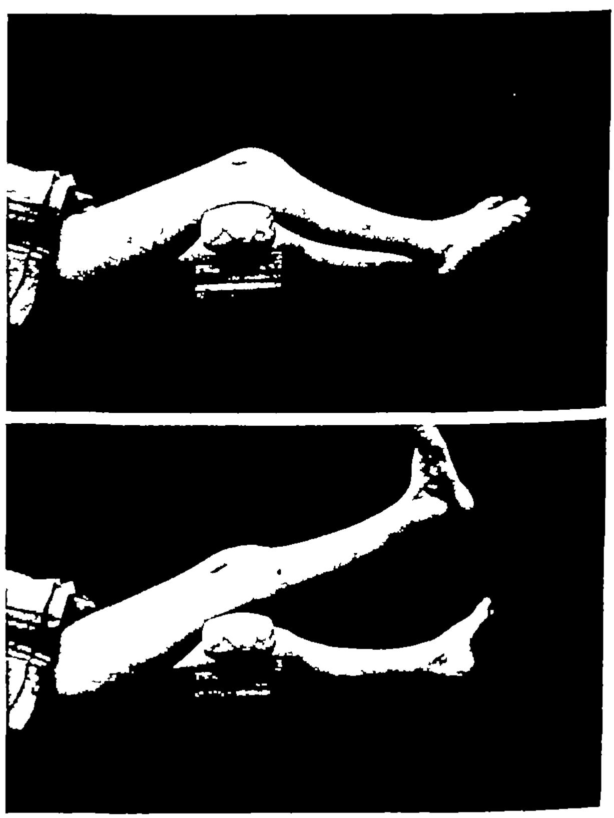

Fig 675
Suppurative arthritis following a wound Active movement after five days' practice Range 135° to 180°

FIG. 677

Tendon sheaths on the anterior aspect of the ankle-joint. (*After Lee McGregor*)

On the anterior aspect three sheaths are found those of the tibialis anticus extensor hallucis longus and extensor digitorum longus (Fig 677) On the medial side there are also three sheaths, those of the tibialis posticus flexor digitorum longus and the flexor hallucis longus (Fig 678) On the lateral side there is a common sheath for the peroneus longus and brevis As in the case of the wrist-joint one must be careful to differentiate between tendon-sheath infection and suppurative arthritis Furthermore when dealing with wounds in this area undamaged tendon sheaths must be respected

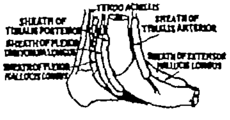

FIG 678

Tendon sheaths on the medial aspect of the ankle joint (*After Lee McGregor*)

METHODS OF IMMOBILIZING AND APPLYING TRACTION TO THE ANKLE-JOINT

Each of the methods about to be described has special uses which will be indicated in the course of the chapter

By plaster of Paris—It is highly important to keep good alignment between the leg and the foot I have found that the best method of holding the foot during the application and setting of the plaster is by means of a board illustrated in Fig 679

The board is 14 in. long, 6 in. wide and ½ in. thick. Nails are driven through the board so that the pointed ends project ¼ in. from its surface roughly one nail to each couple of square inches. The heads of the nails, driven flush into the board, are covered along with the corresponding aspect of the board by ½ in. felt which is affixed with glue

FIG 679

Showing the surface of the board which is applied to the plaster slab on the patient's foot.

In the ankle plaster case a posterior slab of plaster is applied to the back of the leg and the sole of the foot Several turns of plaster bandage are applied promptly around the foot to hold the plantar slab *in situ* and then the board is applied so that the pointed ends of the nails bite into the plantar slab and so prevent the board slipping on the plaster The felted side of the board rests against the surgeon's chest (Fig 680) and he can modify thus the amount of plantar flexion and the

FIG 680

Showing the board in use when applying the plaster cast.

CHAPTER LXIV

WOUNDS OF THE ANKLE AND TARSAL JOINTS

SURGICAL ANATOMY

THE ankle-joint is a pure hinged joint, its strength depends upon the close fitting of the astragalus into the mortice formed by the lower ends of the tibia and fibula Anteriorly and posteriorly the joint capsule is comparatively thin, and it will be noted that the distended synovial cavity bulges, especially behind (Fig 676) On account of the tight mortice formed by the malleoli the ankle is a difficult joint to drain

It is necessary to be cognizant of the best position for ankylosis, which is likely to follow destruction of the joint surfaces When viewed from in

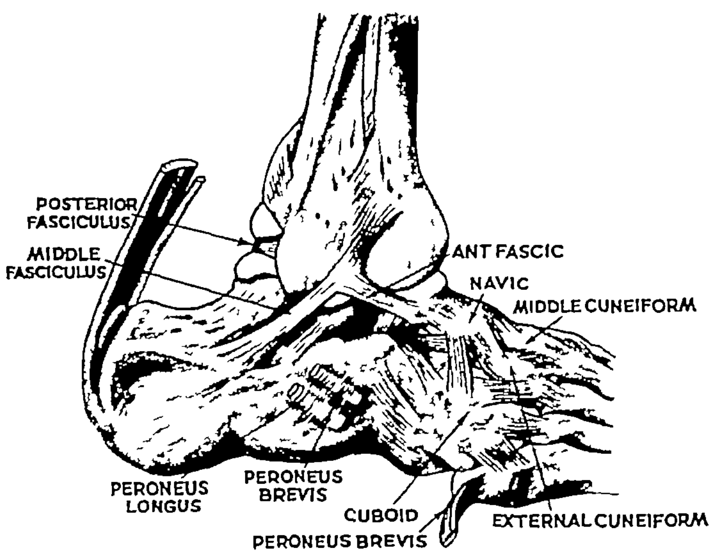

Fig 676

The synovial cavity of the ankle-joint distended (*After Poirier*)

front, straightness without any tilt either outwards or inwards is essential, viewed from the side there should be slight plantar flexion Should the accompanying injury have led to shortening of the tibia, more plantar flexion is advisable, especially in women Following ankylosis of the ankle there is a remarkable degree of compensatory motion in the subastragaloid and mid-tarsal joints

Surrounding the ankle-joint are tendons enclosed in tendon sheaths

and side of the foot with one triangle in line with the outer the other triangle in line with the inner border of the foot About six or seven strips can be applied one behind the other not touching each other and not overlapping on the dorsum of the foot After five minutes to let the glue set tapes are tied to each triangle and fastened to each other under the distal aspect of the foot piece resting snugly in the serrations on the lateral borders of the foot piece

The amount of inversion and eversion can be controlled by the metal plate on the foot piece The whole limb is placed in a Thomas splint By referring to Fig 682 it will be seen that counter-extension is effected not by the ring of the splint against the tuber ischii but by a ring of plaster applied in the following manner beneath the tuberosity of the tibia Pieces of felt are fitted around the upper part of the tibia A cover of plaster of Paris is applied over this felt and by more plaster bandages this cuff of plaster is fixed to the bars of the Thomas' splint In this way effective immobilization and traction are possible It is unnecessary to have the Balkan beam which is shown in Fig 682 all that is required is a prop to keep the patient s heel from the bed (Fig 683)

Fig 683
Sinclair s foot piece applied.

By skeletal traction—At the present time skeletal traction is more popular than skin traction. In the case of the ankle joint skin traction is in every way efficient The insertion of Steinmann s nail through the os calcis is not without possible complications, particularly low-grade infection. The use of Finochietto stirrup has even less to recommend it as with this mode of traction necrosis of bone and skin are common.

In my opinion in cases of wounds involving the ankle-joint where a splint as opposed to a plaster has to be employed a Thomas splint is far better than a Braun s Furthermore a patient in a Thomas splint can be transported easily

SPECIAL CONSIDERATIONS OF WOUNDS INVOLVING THE ANKLE-JOINT

It is well known that as far as avoiding amputation is concerned the prognosis of compound fractures involving the ankle-joint is extremely poor if suppurative arthritis cannot be prevented The injured man s foot sock and boot are so often dirty that serious infection following open wounds in this region is probable Furthermore the responsibility of amputating at a good level above the ankle-joint is not nearly as great as is amputation in many other situations This combination of circumstances makes it probable that in some instances amputation is performed when a useful foot might have been preserved. In the pages which follow operative procedures will be described which, it is hoped, will help the surgeon to preserve the foot in a greater number of cases

inversion or eversion whilst moulding the plaster bandages around the patient's leg and ankle As soon as the plaster has set firmly, the board is removed and a flat plantar surface is left which is well adapted for a walking plaster

By Sinclair's wooden foot-piece—If the surgeon prefers to use traction the best way to apply it is by means of Sinclair's foot-piece The impedimenta required are shown in Fig 681

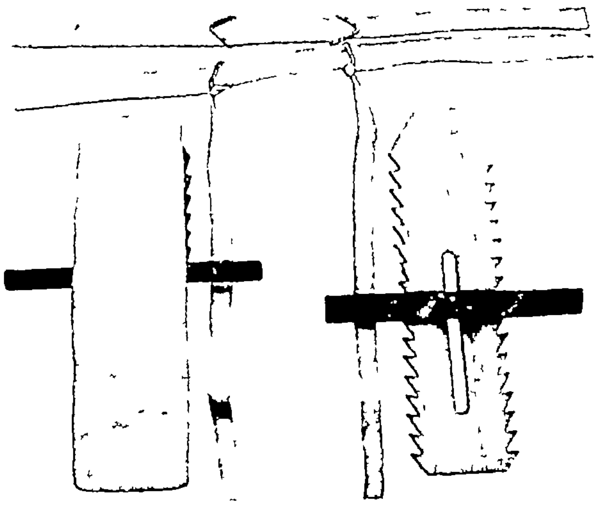

Fig 681
Articles employed in the application of Sinclair's foot-piece

A The wooden foot piece, 12 in long, 4 in wide, ½ in thick and with ½ in serrations along each side

B Felt to pad the plantar aspect of the foot-piece and shaped to the arch of the foot

C The cross-bar made of metal and fitted with bolt and butterfly nut The bolt has a square shoulder at its base to prevent rotation in the slot of the foot-piece The cross-bar is fitted with tapes at its ends and traction on these tapes determines the amount of extension It can be adjusted (1) up and down relatively to the ends of the foot-piece and (2) at any angle to the line of the foot-piece The former adjustment controls the depth to which the limb sinks between the bars of the Thomas' splint, the latter adjustment controls the amount of rotation of the limb

Further are required—

D Strips of flannel 1 in wide, of varying lengths, but averaging about 8 in

E A pair of triangular rings, with 1-in sides, to each strip of flannel These are made from ordinary brass curtain rings with a pair of pliers

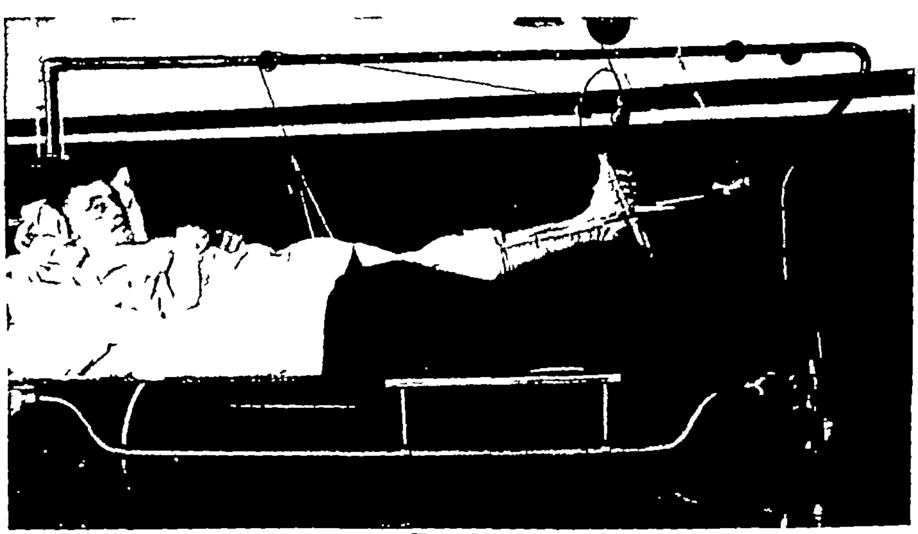

Fig 682
Sinclair's wooden foot piece in use with a ring of plaster of Paris surrounding the limb beneath the tuberosity of the tibia fixed to the bars of a Thomas' splint Counter-extension is effected from this fixed point

The sole and sides of the foot are painted with Sinclair's glue A pair of triangles is threaded on each flannel strip and the strip applied to the sole

in Fig 684 It starts at the posterior border of the fibula 2½ to 3 in above the tip of the external malleolus It extends down the posterior border of the fibula curves round the tip of the malleolus and runs forwards and slightly downwards to the dorsal aspect of the cuboid The tendons of the peronei are freed from the posterior border of the fibula and retracted by means of a loop of gauze The joint between the head of the astragalus and the scaphoid is opened and the capsule between these two bones divided freely The level of the inferior surface of the head of the astragalus is thus seen and on this level posterior to the joint lies the interosseous astragalo-calcanean ligament (see Fig 680)

FIG 684
Incision for astragalectomy

With the forepart of the foot inverted strongly a stout narrow scalpel is inserted backwards and inwards so as to divide the fibres of this inter

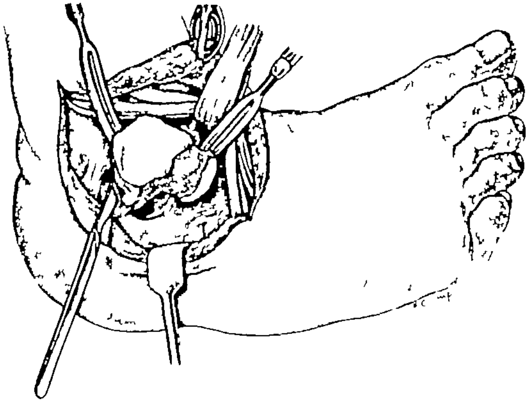

FIG. 685
Astragalectomy

osseous ligament completely thus opening into the posterior astragalo calcanean joint When this step has been completed the tarsal bones under the astragalus can be dislocated by inverting the foot (Fig 685) If the astragalus be whole the neck can be held with lion forceps while the bone is freed from its bed by a stout scalpel working close to the bone at the inner side A structure which can give difficulty at this stage is the

TREATMENT OF RECENT WOUNDS INVOLVING THE ANKLE-JOINT

By inspection it may be obvious that the ankle-joint is involved in other instances the position of the entry and exit wounds makes it probable or certain Likewise the preliminary radiograph may reveal the information It is possible, however, that involvement of the ankle-joint is only discovered when the wound is being excised, perhaps by the escape of a few drops of glairy synovial fluid or the removal of a fragment of bone covered with cartilage, which has obviously come from one of the bones entering into the joint It cannot be repeated too often that when the superficial wound has been excised fresh instruments should be used for attending to the bones and joint

Cases where the wound involves the ankle-joint will fall into three categories —

A The capsule has been wounded but there is little, if any contamination of the joint

B Deep contamination is probable and|or the articular cartilage severely damaged

C The injury to the ankle-joint is so gross as to make it improbable that a functional foot can be preserved

Class A—After the wound or wounds have been excised in the orthodox manner, and severed tendons trimmed and united or left for secondary suture, the wound in the synovial membrane is trimmed very sparingly and an attempt made to close it, in practice this is seldom possible If the skin can be approximated without tension, the wound can be sutured loosely

It is in this class of case that treatment on a Thomas' splint with a Sinclair's foot-piece is admirable, for it allows inspection of the wound Alternatively a Steinmann's nail can be inserted through the os calcis and a Böhler-Braun splint employed, but for reasons stated I do not recommend it

Class B—Attention is directed especially to this class, which is not uncommon To preserve the malleoli is extremely important, the loss of the astragalus is of comparatively little moment, and here lies a possibility of saving a useful foot in many cases of contaminated wounds involving the ankle-joint When the astragalus has been removed, there remains a cavity which can be cleansed adequately, and even if infection ensues, pus is given a free exit

Apart from the viewpoint of preventing suppurative arthritis, astragalectomy is indicated if the astragalus is fractured with displacement, and most certainly if the fracture involves two of the three joints in contact with the astragalus

Astragalectomy—Unless there is a clear indication for using a wound as an avenue of approach, a fresh incision should be employed for removal of the astragalus The limb rests on its inner side and it is an advantage to have the foot nearly over the end of the table An excellent incision is shown

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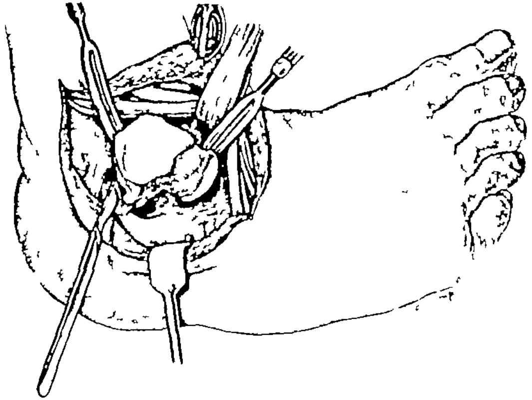

Fig. 685
Astragalectomy

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Fig 684
Incision for astragalectomy

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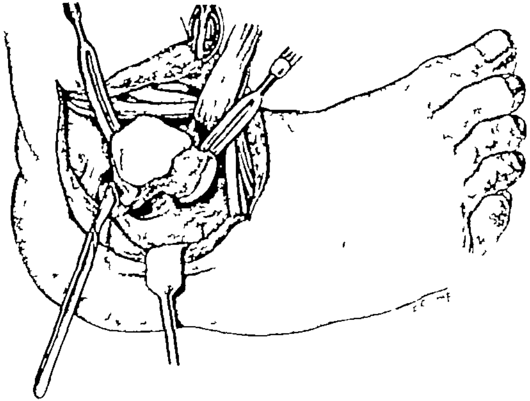

Fig. 683
Astragalectomy

osseous ligament completely thus opening into the posterior astragalo calcanean joint When this step has been completed the tarsal bones under the astragalus can be dislocated by inverting the foot (Fig 685) If the astragalus be whole the neck can be held with lion forceps while the bone is freed from its bed by a stout scalpel working close to the bone at the inner side A structure which can give difficulty at this stage is the

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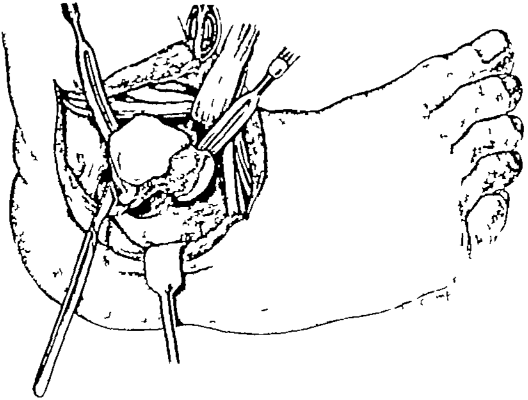

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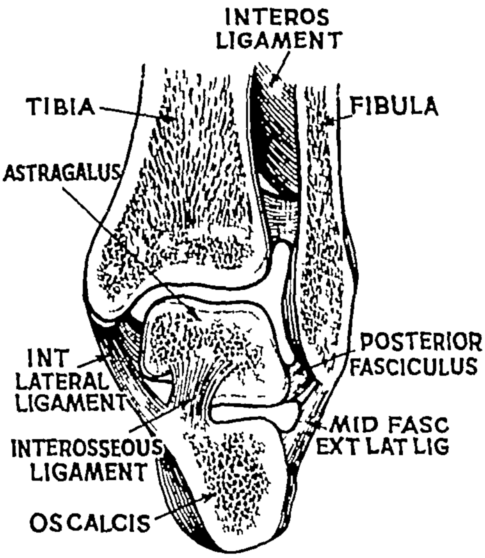

FIG 686

Coronal section of the ankle-joint showing particularly the interosseous astragalo-calcanean ligament

tendon of the flexor hallucis longus, which runs in a groove on the posterior surface of the astragalus, but if considerable traction on the astragalus is maintained the tendon can be freed and the bone removed Naturally it is easier to remove the bone when it is intact than if it be fractured, but there is no difficulty in removing the whole astragalus when the three joints in contact with it are free from ligamentous attachments The division of the ligaments on the inner side should be particularly free, for this allows the foot to be pushed back so that the mortice of the ankle-joint fits over the forepart of the os calcis Occasionally it may be necessary to excise a portion of the sustentaculum tali to permit this displacement

When the astragalus has been removed the cavity is filled lightly with vaseline gauze, and vaseline paste is applied plentifully to the skin around A below-the-knee plaster case is then applied When applying this plaster the foot should be displaced backwards so that the tibia rests on the forepart of the os calcis just behind the scaphoid Again, the board with nails embedded is especially valuable in maintaining the correct position during the application of the plaster

Class C—When the nature of the injuries make it obvious that a functional foot cannot be preserved, the choice lies between performing Syme's amputation or amputation of the leg at the modern seat of election Which of these two procedures is adopted will depend largely on the character of the injury to soft parts

In the present war injuries to both legs have been fairly common If the patient must lose both feet, the possibility of performing tibio-calcanean fusion may arise as an alternative to amputation This consists of removing the cartilage from the ankle mortice and the upper surface of the os calcis Half an inch of the anterior end of the os calcis is also removed All other bones of the foot are removed (Fig 687) and the os calcis is fitted into the mortice of the ankle joint denuded of its cartilage and malleoli This stump will render the patient independent of an artificial limb at home

FIG 687

When the os calcis, the heel flap and sufficient undamaged skin is available, tibio cal canean fusion is a possible expedient under exceptional circumstances

THE TREATMENT OF LATE WOUNDS INVOLVING THE ANKLE-JOINT

If there are no visible signs of inflammation and especially if the astragalus is fractured, it may be wise to perform astragalectomy In this instance the cavity can be smeared with Bipp The paste must be prepared in conformity with Rutherford Morison's teaching and be of the proper consistency One of the objections to the use of Bipp is that it

interferes with the interpretation of radiographs but in the case of the ankle-joint this objection has not the same significance as in the case of a fractured bone Again the cavity is filled lightly with vaseline gauze and a plaster cast applied

When the wound is visibly infected amputation is usually indicated If there is any question of a spreading or anaerobic infection a guillotine amputation just above the malleoli is usually a wise procedure (see Chapter LXIX) In due course when the infection has abated secondary amputation at the modern seat of election can be performed

INFECTIVE ARTHRITIS

As explained already purulent arthritis of the ankle-joint is a disappointing complication of compound fractures in this neighbourhood and because of the anatomical arrangement of the joint its treatment is inclined to be unsatisfactory

As with other joints the vulnerable tissue with no adequate blood supply is the articular cartilage which becomes softened and liable to destruction from pressure To obviate pressure is the primary object of traction. Inflammation in a joint leads to spasm of surrounding muscles, and it is this which causes the joint surfaces to become pressed together and results in sloughing or ulceration of the cartilage In applying traction to an inflamed joint only enough is required to overcome muscular spasm If more than this is employed, the pull operates upon inflamed and soddened ligaments, consequently pain is increased instead of being relieved and the stability of the joint is permanently prejudiced. So it comes about that if in the course of treatment pain is relieved at first and then for no obvious reason returns, it is quite likely that over traction is the cause and certainly lessening the amount of extension should be tried.

In cases of purulent arthritis of the ankle joint there is often a sympathetic effusion into the tendon sheaths It is possible that suppurative tenosynovitis may be confused with purulent arthritis but as the former condition is likely to be confined to one set of the synovial tendon sheaths (see Figs 677 and 678) the differential diagnosis is not usually difficult

Aspirating the joint—Gas and oxygen anæsthesia is advisable The ankle joint can be punctured anteriorly either between the lateral border of the extensor digitorum longus and the external malleolus or between the medial border of the tibialis anticus and the internal malleolus The needle should be introduced with a slightly downward tilt (Fig 688)

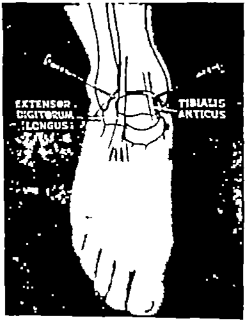

Fig 688
Aspirating the ankle-joint

As much fluid should be withdrawn as possible

(a) If the fluid be transparent with a few flakes of lymph good has been done although the aspiration may have to be repeated in forty-eight hours

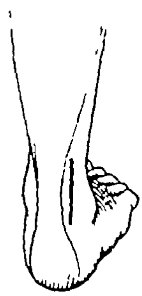

Fig 689

Posterior incision for drainage of the ankle-joint If necessary a second incision on the inner side of the tendo Achillis can be made

if clinical improvement is not maintained Stained films should be prepared from the fluid *for evidence of the nature* of the organism

(*b*) If the fluid be turbid it is hopeless to obtain a mobile joint, and the best that can be expected is ankylosis If the surface wounds are reasonably clean and the organism is anything but hæmolytic streptococcus, then drainage of the joint should be tried

Incisions for draining the joint—The best drainage is afforded by making a short vertical incision at one or both of the two points recommended for puncture Through the opening a probe is passed into the joint A larger posterior incision is then made lateral to the tendo Achillis (Fig 689) lateral the better to avoid vessels and nerves Aided by the probe the posterior pouch (see Fig 676) can be opened adequately A tube is inserted into the posterior wound but not into the joint By adequate traction and immobilization and this method of incision, the best simple dependent drainage of the joint is afforded

(c) If the fluid be associated with a hæmolytic streptococcus or be frankly purulent with comparatively clean superficial wounds, I would try astragalectomy before resorting to amputation The cavity left by astragalectomy should be drained freely behind the external malleolus, and an oral course of sulphonamide instituted Under these circumstances there *is no reason why the infection should not be got under control*

THE TARSAL-JOINTS

SURGICAL ANATOMY

In addition to the ankle-joint there are six synovial joint cavities in connection with the tarsal bones (1) The cavity over the head of the astragalus, (2) the posterior astragalo-calcanean joint, (3) the calcaneo-cuboid joint, (4) the joint between the cuboid and the bases of the fourth and fifth metatarsals, (5) the joint at the base of the first metatarsal and (6) a complicated cavity between the scaphoid and the individual cuneiform bones (Fig 690)

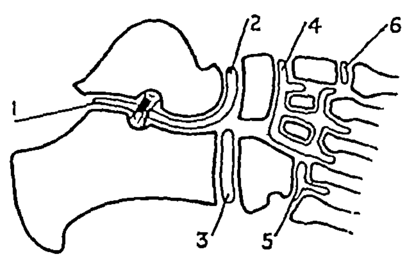

Fig 690

Excluding the ankle joint, there are six synovial joint cavities connected with the tarsal bones

For a supple foot with spring these joints are necessary, for a foot which will serve to bear weight and allow walking they are unnecessary, but for such a good result the bones must be in alignment, ankylosis must be sound and the metatarso-phalangeal joints must be free *For the foot as a weight-bearing structure see p* 735

GENERAL CONSIDERATIONS OF WOUNDS INVOLVING THE TARSAL-JOINTS

If the tarsal joints are wounded invariably one or more tarsal bones are involved *Such wounds have proved not uncommon in the present war* (Fig 691) The tarsal bones are slow to overcome sepsis and heal, but as long as infected joints are drained the alignment of the foot is preserved and the first metatarsal is intact it is always worth persevering with conservative treatment In order to maintain alignment of the foot and prevent equinus at the ankle the most efficient splintage is by plaster casts In the early stages of treatment the leg is kept raised on a Braun s splint or an inclined plane

Fig 691

Compound fracture involving the astragalo-calcanean joint from a bomb fragment

When the metatarso-phalangeal joint of the *big toe is affected traction can be applied by a* strip of Cramer wire embedded in a foot plaster and reaching 4 in. beyond the toe Pulp traction can be employed or skin traction effected by gauze strips fixed to the big toe by glue Should the joint ankylose 20° of extension is the optimal position In this position the patient may find that he can walk with reasonable comfort especially when a metatarsal bar has been fitted to the sole of the boot When ankylosis occurs in any other position it is best to excise the proximal half of the proximal phalanx

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SECTION XIV

WOUNDS OF THE HAND AND FOOT

CHAPTER LXV

WOUNDS OF THE HAND

IN the case of the hand the penalty resulting from the failure of primary suture after excision of wounds is so heavy that primary suture should be restricted to the occasional exceptionally favourable case Wounds of the hand are often associated with compound fractures consequently radiographs are most desirable but if they cannot be obtained without delay they should not be insisted upon

The use of a tourniquet to secure a bloodless field—A tourniquet should be applied as the first step in the operative procedure before the cleansing of the skin An Esmarch s bandage is satisfactory but precautions must be observed in its use First the arm is raised The turns start at the fingers and continue progressively up the forearm The bandage is then tied firmly below the elbow and the distal turns are undone up to the wrist A pneumatic tourniquet or the arm bag of a blood pressure apparatus inflated to a pressure of 250 mm should be used when it is necessary to apply a tourniquet above the elbow A pneumatic tourniquet has a further advantage in that its pressure can be reduced to allow bleeding vessels to be identified and secured after which it can be reinflated until the operation is completed When the injury is confined to the distal half of a digit a small rubber catheter or narrow strip of sheet rubber is first applied round the base of the finger and clamped with a hæmostat

Local anæsthesia and the indications for its use—When the injury is restricted to the distal phalanges of one or more fingers general anæsthesia is unnecessary Ring anæsthesia with 1 per cent freshly prepared novocain without adrenalin is preferable The anæsthetic solution is injected round the base of the finger distal to the tiny tourniquet (see above) commencing the injection into and then deep to the skin on the dorsum and sides (Fig 692) before the sensitive palmar skin is injected An interval of five minutes must be allowed to elapse before the operation is commenced

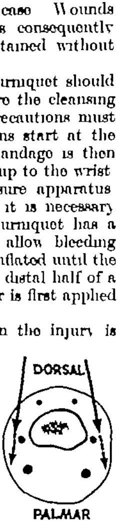

Fig 692

"Ring" anæsthesia of a finger Note that the solution is introduced from the dorsum

In the hand proper infiltration anæsthesia renders tissues semi translucent thus aiding the location of foreign matter To commence with the skin of the palm must not be pricked it is much too painful Infiltration is begun from the dorsum and proceeds through the thickness of the hand to infiltrate the tissues of the palm (Fig 693) In due course an intradermal injection of the palmar skin is effected by the needle introduced from the dorsum After this step the needle can be

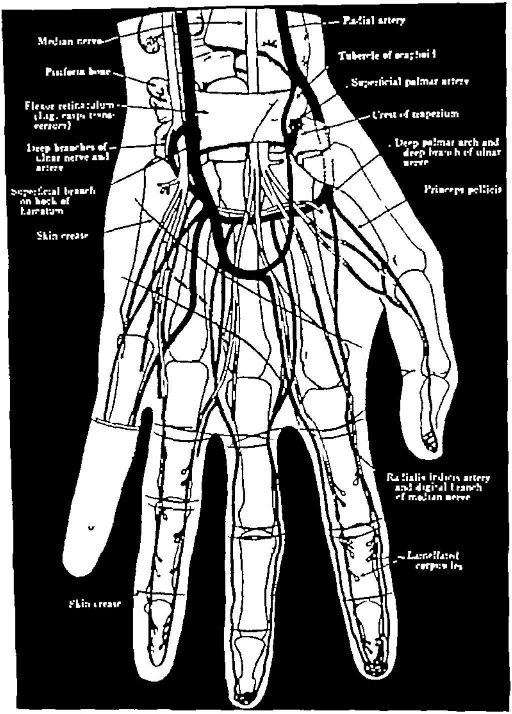

FIG. 691

The nerves and arteries of the hand shown in relation to the skin creases.
(*Jamieson.*)

reintroduced painlessly from the palmar aspect Infiltration must be extensive and include the skin as well as the subcutaneous tissues Local anæsthesia has many advantages The chief decision to be made before employing it is, can the skin be cleansed adequately without a general anæsthetic?

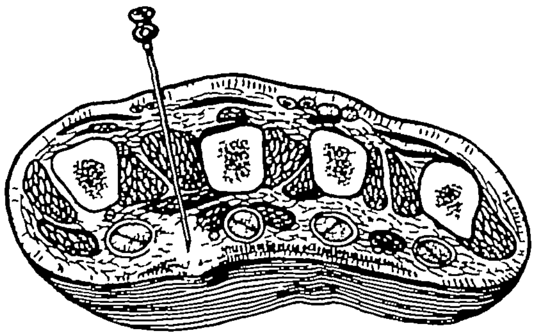

FIG 693

Note, again, that local anæsthetic is introduced through the dorsum even when the palm is to be anæsthetized

Cleansing the skin — After a tourniquet has been applied, attention should be directed to cleansing the skin of the hand and forearm This is a most important consideration If thorough skin preparation can be carried out without an anæsthetic, so much the better, for it permits the use of local anæsthesia for the operation If local anæsthesia is to be used, the cleansing of the skin, important at all times, is doubly so, and the greatest care must be applied to sterilizing the dorsum of the hand through which the anæsthetic is injected invariably Often a general anæsthetic is necessary, not so much from the point of view of the actual operation, but to spare the patient pain when scrubbing the skin near traumatized tissue Ablution of the exposed portions of the hand and forearm is undertaken with soap and water before removing that portion of the dressings in contact with the wounds The soap is dissolved in hot water which has been boiled, and when required for use it is mixed with an equal quantity of warm sterile water If the skin is engrained with dirt and blood, ether or ether soap is used Finally, the soapy solution is washed away with sterile water or saline solution The table on which the limb rests and the whole operation field are now covered with sterile towels and the surgeon changes his gloves

Wound excision—The dressing covering the wounds is removed and the skin edges are pared carefully with curved scissors If need be, the original wounds are enlarged by incisions so placed as not to wound tendons, important blood vessels, or nerves (Fig 694) These incisions should, as far as possible, be made in a transverse direction as curved or sigmoid extensions of the wound, which is then explored systematically with the aid of suitable retractors All foreign material and loose fragments of bone must be removed, and all contused, soiled and devitalized tissue excised

If before the application of the tourniquet it was obvious that the blood supply of one or more fingers was seriously jeopardized, amputation should be carried out forthwith, should there be doubt concerning viability, the tourniquet is released after completion of the wound excision, so that the appropriate level for the amputation can be determined Fingers or portions of fingers, of which the bones are hopelessly shattered and the tendons destroyed, should be disarticulated, but when there is a suitable portion of intact skin with a good blood supply connected with the fingers it can be utilized to cover skin defects on the palm or dorsum of the hand (Fig 695)

Every effort must be made to save as much as possible of a wounded

A simple and useful type of palmar cock up splint designed to hold the hand in the position of function, is described in Kanavel's book. It is light in weight fairly rigid and made out of thin, hard, sheet aluminium (Fig 697) A simple splint such as this can easily be cut out of aluminium sheeting with tin-cutting shears, and it can be altered to suit the particular case A piece of rubber cricket bat grip can be used to cover the rounded hand piece and the splint itself can be padded with sheet sorbo rubber If rubber is used, the splint can be applied to the hand while infection is present Extension arms or a transverse volar loop can be devised easily and added to this basic splint to serve as attachment for finger tip extension either in an extended or flexed position.

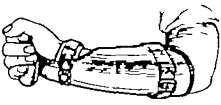

Fig 697

Palmar splint to hold the hand in the position of function It can be made out of sheet aluminium. (*After Kanavel*)

In the position of function the hand is dorsiflexed at the wrist to an angle of 45° while the fingers are flexed at 45 at their metacarpo phalangeal and interphalangeal joints The thumb is rotated and abducted so that its flexor surface is opposite the flexor surface of the index finger (Fig 698) Even when there is a high degree of impairment of function with stiff joints fibrosis of muscles and nerve lesions it is still possible to carry out a large number of important actions with a hand in the position of function

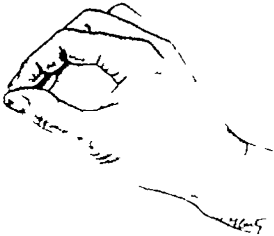

Fig 698

Hand in the "position of function"

Wounds which have been sutured after excision or clean open wounds or stumps may on condition that the patient remains in hospital be treated as Böhler recommends without or by early removal of all dressings A protective scab soon forms when wounds are exposed to light and air By constructing a cage of Cramer wire around the hand (Fig 699) and covering the cage with a layer of gauze wounds are protected without contact with dressings

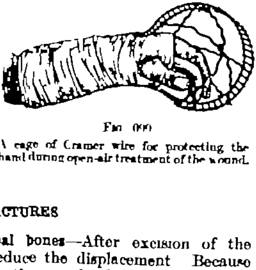

Fig 699

A cage of Cramer wire for protecting the hand during open-air treatment of the wound.

COMPOUND FRACTURES

Compound fractures of the metacarpal bones—After excision of the wound an attempt should be made to reduce the displacement Because of laxity of the capsule and ligaments traction on the fingers is ineffective unless the lateral ligaments of the metacarpo phalangeal joints are rendered tight by flexion to a right angle (Jahss) The fingers of the fractured metacarpals should be maintained with their metacarpo phalangeal and proximal

thumb Even the salvage of a small stump is a tremendous asset for future useful function To achieve this, providing always excision has rendered the area virtually aseptic, it may be necessary to cover the raw extremity with free whole thickness skin grafts or with pedicle or "pocket" grafts from the skin of the lateral abdominal wall In cases admitted after the safe period, or in those in which infection is already present, one must wait until the denuded area is covered with healthy granulations before applying the grafts Throughout all stages of treatment and under all conditions the thumb or its stump must be separated from and opposed to the fingers, and held in the position essential for useful function

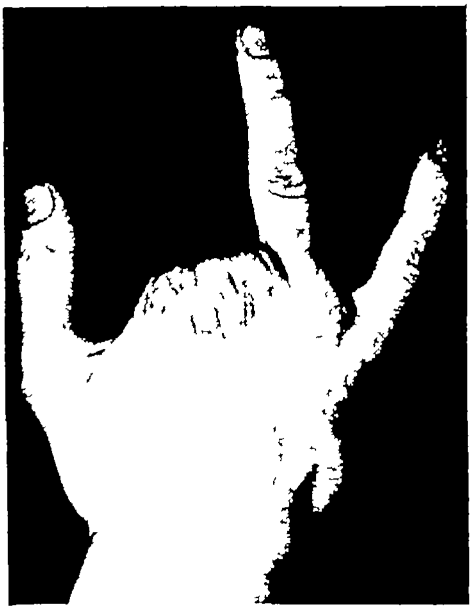

FIG 695
"Deboned" digital flaps were used to cover a skin defect on the dorsum in this case

In war wounds severed tendons and nerves should rarely be sutured at the primary operation (see Chapters LII and LIII)

The tourniquet is now released and spurting vessels tied with fine catgut The majority of war wounds of the hand should be packed lightly after excision with selvadged ribbon gauze of suitable width, soaked in flavine and paraffin, which is an excellent dressing in the early but not in the later stages of healing

Raw surfaces or open stumps are protected from adhesion to the dressings by covering them with strips of vaseline gauze or tulle gras

Immobilization during healing—A great difficulty in treatment of injuries of the hand lies in the fact that the lesions are so often multiple They resemble farmers' crops conditions which suit one are unfavourable for the others So it comes about that immobilization, which is essential for healing of the injuries to the soft parts and bone, is prejudicial to preservation of function in the mobile structures For this reason the hand must be maintained throughout treatment in such a position that the residue of movement in the wrist and fingers may be of maximal use Kanavel insisted on this essential primary principle and aptly described it as the *position of function* It was in order to maintain the position of function that Sir Robert Jones introduced the cock-up splint (Fig 696)

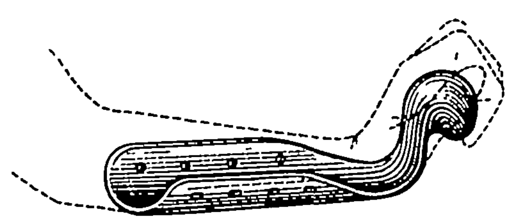

FIG 696
Jones' cock-up splint

CHAPTER LXVI

INFECTED WOUNDS OF THE HAND

WHEN for some reason the wound has not been excised and the safe period for this procedure has passed the general principles involved differ but little from those of infected wounds in general (see Chapter XI) As in wounds of other parts vigilance must be exercised in recognizing promptly signs of gas gangrene and if gas gangrene is present affected muscle must be excised

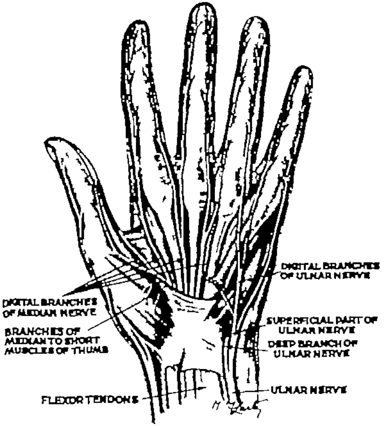

FIG 702

Flexor tendons and nerves in the palm after removal of palmar fascia.
(*After Spalteholz.*)

Special points in operative treatment—The advisability of the use of a tourniquet and the fundamental necessity of thorough skin preparation is precisely the same as set out on pp 723 and 724 It should be obvious that in this instance local anæsthesia is absolutely contraindicated

In the absence of an anaerobic infection, débridement must be particularly gentle always envisaging the intrinsic anatomy of the hand especially the

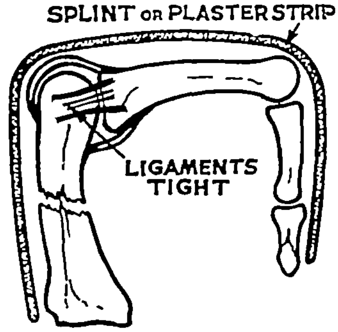

FIG 700
The correct position to immobilize the finger in the case of a fractured metacarpal bone

interphalangeal joints at an angle of 90° by a dorsal splint of Cramer wire, aluminium or a plaster slab (Fig 700)

Compound fractures of the phalanges—I have not found that finger-tip extension (applied to a stainless-steel pin transfixing the pulp) can be maintained for a sufficient period to be helpful, furthermore, pulp extension tends to decrease the blood supply and impair the vitality of the injured tissues (McNealy and Lichtenstein) Consequently such cases have been treated on palmar finger splints made of Cramer wire or aluminium strips These are first moulded on the surgeon's own finger, padded, and then applied to the patient's fractured digit flexed to an angle of 45° at its metacarpo-phalangeal and distal interphalangeal joints, and to 90° at the proximal interphalangeal joint The digital splint is incorporated in a forearm plaster case (Fig 701) When there are extensive wounds on the palm or on the palmar aspect of the fractured finger, the splint can be applied to the back of the flexed finger and incorporated with a plaster slab fixed to the dorsum of the forearm and hand The uninjured fingers must be left free for early active movements to prevent capsular adhesions

FIG 701
Digital splint incorporated in a forearm plaster case

Care should be taken to follow Watson Jones' injunction that "each finger must be immobilized in such an axis of flexion that it points to the region of the scaphoid tubercle," because the flexed fingers do not normally lie parallel If each finger is flexed in turn, it will be found that they converge and that the tip of each of them touches the palm near the base of the thenar eminence

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This technique evolved by Sister S J Wray of the Royal Infirmary Sheffield who has had an exceptionally large experience of these cases has proved excellent in the class of case indicated It should be noted that Sister Wray approves of the dry method for the majority of cases

INFECTION OF FLEXOR TENDON SHEATHS

(Index, middle and ring fingers)

The classical signs of suppurative tenosynovitis are intense pain in the affected finger with fever and general malaise The finger is swollen symmetrically and is held rigidly in a semi flexed position There is acute tenderness over the course of the sheath

These signs are not always present when this serious complication arises after a gunshot injury of the hand The rigid flexed position of the finger is caused by tension within an intact sheath and it disappears as soon as the sheath ruptures or is opened by a surgical incision It is for this reason that if the sheath has been opened by the injury physical signs are anomalous The only constant sign is intense tenderness on pressure over the proximal cul-de-sac of the sheath in front of the head of the metacarpal bone (Iselin)

Iselin compares the synovial cavity of a flexor tendon sheath to a thermometer with a capillary tube above and reservoir bulb below If the tube is opened the liquid does not flow but it does so immediately the reservoir is opened

Applying this principle he considers that digital incisions are quite ineffective in the treatment of suppurative tenosynovitis He recommends through-and through commissural incisions which open exclusively the proximal cul-de-sac of the sheath.

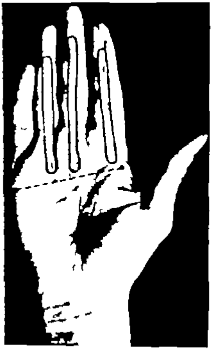

Fig 704

An imaginary line joining the lateral distal ends of the vertical palmar crease and the medial extremity of the distal palmar crease marks the proximal limits of the three culs-de-sac.

ISELIN'S METHOD OF DRAINING THE FLEXOR TENDON SHEATHS

(Index, middle and ring fingers)

Surgical anatomy—Before undertaking operative treatment by this method it is essential to understand the surgical anatomy upon which the principles are based The flexor tendon sheaths of the index middle and ring fingers end blindly The imaginary line which marks the proximal limit of the three culs-de-sac is as follows it runs from the outer and distal end of the vertical palmar crease to the inner end of the distal palmar flexion crease (Fig 704) The proximal cul-de-sac is the weakest part of the sheath and it is here that rupture occurs when the sheath

arrangement of tendon sheaths and nerves (Fig 702), lest, perchance, the intervention becomes mischievous

Immediate after-treatment is a matter of prime importance and one which cannot be stereotyped, but certain fundamental principles can be emphasized —

(*a*) The hand and forearm should be immobilized in the position of function (see Fig 698) by one of the several methods detailed in the previous chapter
(*b*) The limb should be elevated
(*c*) Sulphonamide therapy is begun
(*d*) Access should be afforded for frequent examinations in order that the surgeon may have an opportunity to diagnose promptly such complications as tendon-sheath infection or fascial-space involvement This requirement prevents the adoption of the completely closed plaster which might well be employed in parallel cases elsewhere

Regarding local treatment of infected wounds of the hand, there is little doubt that a radical change is in process of taking place All are agreed that arm baths, so popular until a few years ago, should not be used in these cases Many surgeons have banished hot moist dressings altogether Fomentations, in particular, have the great disadvantage of being painful, and by scalding and macerating the skin they render the diagnosis of complications far more difficult Again, if hot moist dressings are employed, it is more difficult to design methods of immobilizing the hand efficiently

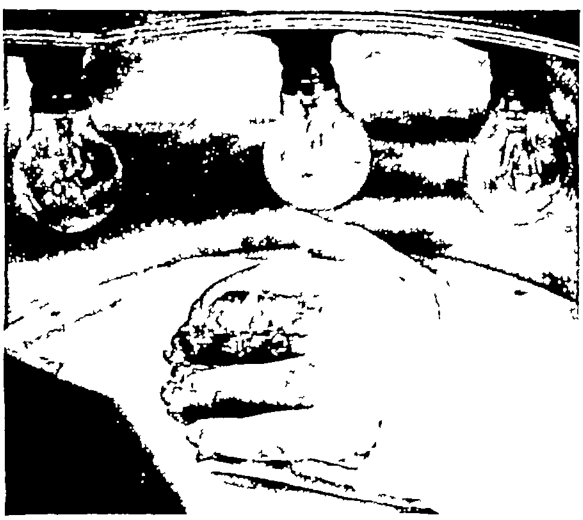

Fig 703
One method of applying dry heat to an infected hand

Dry heat from electric bulbs (Fig 703) or artificial heliotherapy applied for two hours at a time would appear to offer all the advantages, without the disadvantages, of hot moist dressings in any shape or form

If aqueous solutions are withheld, vaseline gauze or acriflavine in glycerine are suitable dressings to be applied to the wound itself

In a few cases, particularly those associated with sloughing tissues, the above methods are not accompanied by satisfactory progress, and it may be considered advisable to change to the "wet" method for a day or two *With the hand still immobilized* "rotation dressings" are applied and changed every four hours Used in turn are

1 Eusol (normal strength)
2 Hydrogen peroxide (10 per cent).
3 Magnesium sulphate (5 per cent).
4 Normal saline

the procedure presupposes the absence of partitioning adhesions which, however usually do not form in recent infections. In my own experience Iselin's operation has proved successful, but I think distal ends of the incisions should be kept proximal to the intermetacarpal ligament because division of that important structure may cause troublesome recurrent dorsal dislocation of the distal end of the metacarpal. For the same reason it is inadvisable to split the webs too deeply in opening abscesses of the commissural or lumbrical spaces.

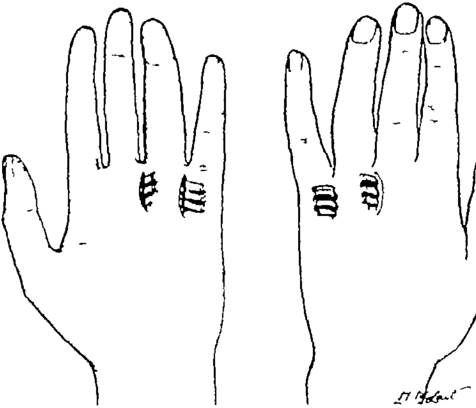

FIG 07

Iselin s method of draining a flexor tendon sheath. Four commissural incisions open the superior cul-de-sac at the site of election and permit introduction of two transfixion rubber strips. In the case illustrated the tendon sheath of the ring finger was infected

Supplementary measure when drainage is unsatisfactory—As has been emphasized if the distal cul-de-sac has been opened reasonably early drainage of the whole tendon sheath is assured Occasionally in late cases drainage is unsatisfactory owing to intrathecal adhesions Again if suppuration should persist from the wound (original accidental or operative) in the digital portion of the tendon sheath in spite of the fact that incisions through the hand have discharged satisfactorily for three or four days it is certain that the drainage from the basal incisions is unsatisfactory

Under the foregoing circumstances partitioning off of the sheath may with certainty be inferred and must be dealt with by dividing the first pulley on one side thereby permitting free drainage of the basal portion of the sheath

Lateral division of the first pulley—One must not forget that the proximal pulley is long and extends into the palm above the digito palmar crease It cannot be divided completely by adding an incision on the lateral aspect of the finger to the existing palmar incision, for the proximal part of the

becomes distended with purulent exudate Iselin, therefore, has designed his operation to drain the cul-de-sac by the most direct route which is through the commissure

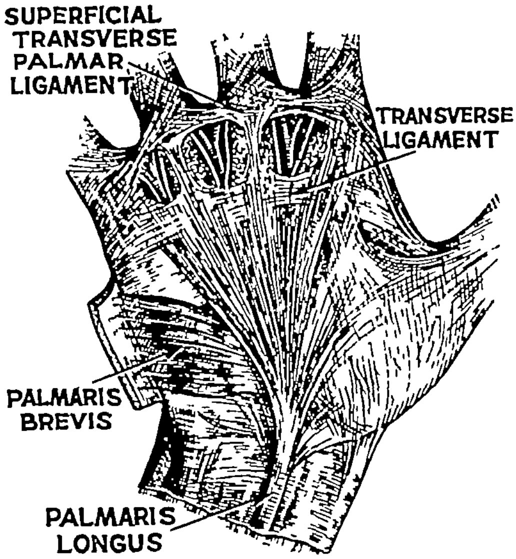

FIG 705

Dissection showing the interdigital commissures (*After Iselin*)

"Commissure" is a French term and a highly desirable one to employ, for it includes, in addition to the web, the web space and cellular tissue between the bases of the fingers (Fig 705) As will be seen in Fig 706, a possible obstruction to free drainage of the distal two-thirds of the tendon sheath, especially in the presence of intrathecal adhesions, is the first pulley which surrounds the sheath Therefore, in some cases it is essential to divide this pulley (see Fig 708)

The operation comprises four incisions, two palmar and two dorsal, through the base of the interdigital web The palmar incisions follow the direction of the intermetacarpal space, opening up both interdigital commissures of the infected finger They average 2 cm in length Proximally they are limited by the imaginary line depicted in Fig 704 Distally they do not reach the free edge of the web After the aponeurosis has been incised, the skin edges are retracted to expose the synovial cul-de-sac, which is recognized easily, because even if it is not distended with pus, it is congested and œdematous The cul-de-sac is opened on each side with a scalpel and the tendon is exposed There is no danger of injury to the collateral nerves and vessels of the finger, because, at this level, they lie considerably deeper than the synovial cul-de-sac, which lies superficially just under the aponeurosis

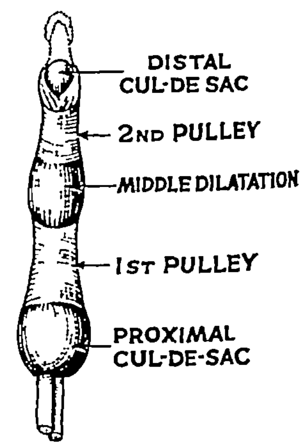

FIG 706

Showing how the first pulley in particular can obstruct free drainage from the proximal cul de sac

Next, a hæmostat is inserted through each palmar incision in turn and pushed back to raise the skin on the dorsum the beak of the hæmostat is then cut down on, and opened to grasp a strip of rubber which is pulled through to project from the palmar incision (Fig 707) The rubber strip traverses the commissural space from back to front and acts as a drain The sheath is not directly drained, it is simply drained by the two strips which lie in contact with the opened cul-de-sac

Proof that this form of drainage is well placed is afforded by the following clinical observations (*a*) So long as pus formation continues the incisions show no tendency to close, (*b*) a digital incision made previously dries up and closes rapidly if supplemented by Iselin's incisions The success of

These classical signs become lost as soon as the bursæ give way and the purulent exudate becomes diffused in the palmar spaces or as is more usual spreads up the forearm in the cellular space which lies deep to the flexor tendons and muscles and in front of the pronator quadratus and the interosseous membrane (the space of Parona) (Fig 710) It was Kanavel in the first edition of his Infections of the Hand (1912) who first recognized the clinical signs of this formidable condition He also described sound principles of treatment based upon surgical anatomy The extension upwards into the forearm (Parona s space) is characterized by a brawny induration that should not be confused with the softness of an œdema No fluctuation should be expected since the accumulation lies too deeply There is loss of the relative swelling immediately above the anterior annular ligament not because this swelling is less but because that of the arm is greater The tenderness may become less The redness is generally greater and spontaneous pain while at first marked subsides rapidly In a definite ulnar or radial bursal infection that has lasted forty-eight hours such an extension should be assumed and an ulnar incision made (Kanavel)

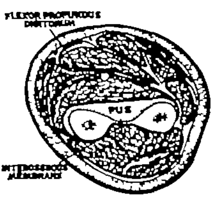

FIG 710
The space of Parona.

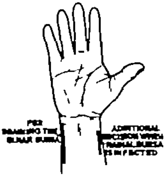

FIG 711
Incisions for draining the radial and ulnar bursæ when the infection is confined to the bursa or bursæ.

Operative treatment — Iselin differentiates between the treatment required in the early case in which the infective process still remains confined to the ulnar and radial bursæ and the treatment of the later case with diffusion of the inflammatory exudate He considers that the *early uncomplicated bursal infection requires lateral forearm incisions only* to drain the upper end of the ulnar cul-de sac and, if need be the radial bursa also For an ulnar bursa infection the ulnar incision suffices (Fig 711) in a radial bursa infection or with infection of both bursæ the more important ulnar incision (which affords dependent drainage in the normal posture of the forearm) is first completed and then supplemented by a short radial incision to permit introduction of a through-and through drain

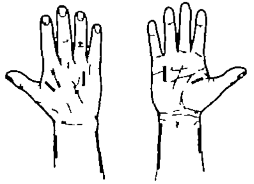

FIG. 712
Incisions necessary when the radial and ulnar bursæ have burst and infection is diffusing

On the contrary *a ruptured bursal tenosynovitis with diffusion always requires additional incisions in the hand* An incision into the digital part of the sheath is useless The incisions shown in Fig 712 enable us to insert

pulley will persist and continue to strangle the sheath To effect its complete division the dorsal route must be followed by prolonging the existing dorsal incision down the finger in the dorso-lateral line, behind the collateral vessels and nerves which are preserved intact in the anterior lip of the wound This large incision brings the base of the tendon sheath into plain view (Fig 708), and the wide pretendinous band which constitutes the pulley can be divided in its whole length close up to its insertion When this step is necessary, one generally finds that the tendon itself is grossly infected, and this is the underlying cause of persistence of the discharge, in which case the prognosis with regard to the function of that digit is hopeless

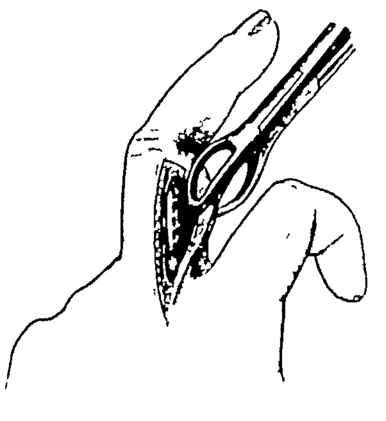

FIG 708

Should drainage of the first cul de sac not suffice, the proximal pulley should be divided on one side only after prolonging the dorsal incision downwards into the finger

(*After Iselin*)

SUPPURATIVE TENOSYNOVITIS IN THE THUMB AND LITTLE FINGER

As is well known, infections of the tendon sheaths of the little finger and thumb are particularly dangerous The tendon sheath of the little finger communicates directly with the ulnar bursa which enfolds the flexor tendons as they pass behind the anterior annular ligament The sheath of the flexor pollicis longus also extends under the anterior annular ligament to form the radial bursal extension The radial and ulnar bursæ generally intercommunicate Thus infections of the sheaths of the little finger and thumb often spread directly to the major bursæ in front of the wrist and endanger the whole group of flexor tendons

Clinical features—When an infection of the major bursæ takes place the condition of the patient bespeaks the serious nature of the infection Pain in the hand and wrist is severe and the temperature rises to 102° to 104° F The hand becomes swollen on its palmar, but especially on its dorsal, aspect

In the case of the little finger, where the sheath extends up to expand directly into the ulnar bursa, the maximum point of tenderness is found just proximal to the distal palmar flexor crease on the ulnar side of the palm (Fig 709)

FIG 709

The site of maximal tenderness in cases of involvement of the ulnar bursa

All the digits become flexed and rigid Both passive and active movements are restricted and exquisitely painful

hindrance across the surface of the pronator quadratus behind the tendons to the external border of the forearm When drainage of the radial bursa is indicated a hæmostat can be passed across transversely behind the tendons and an incision made on to its beak keeping well to the radial

FIG 715

An additional incision in the line of the ulnar incision is necessary when pus has extended far into the forearm.

border of the bone the better to avoid injury to the radial artery If the infected bursa or bursæ have burst already pus escapes as soon as this deep space is opened if it does not the proximal cul-de sac can be made to bulge by pressure upon the palmar portion of the ulnar bursa (Fig 714) The base of the bursa is then opened and drained by a rubber strip (When pus has been allowed to track up the forearm an additional short incision (Fig 715) in the line of the ulnar incision is indicated)

INFECTION OF THE FASCIAL SPACES

We have seen that the pus in suppurative tenosynovitis of the three middle fingers tends to collect in the proximal blind end of their sheaths from which it may burst into the fascial spaces of the palm

These fascial spaces may also be infected (*a*) directly from a wound of the palm or (*b*) from osteomyelitis (primary or secondary to a compound fracture) of one or more metacarpal bones Fascial space infections may in turn involve the radial and ulnar bursæ

The two fascial spaces in the palm which are of major importance are the middle palmar space which lies medial and the thenar space which is lateral to the septum which separates them and is attached with the transverse head of the adductor pollicis to the front of the middle metacarpal (Fig 716)

The middle palmar space lies deep to the flexor tendons and in front of the fascial covering of the interossei

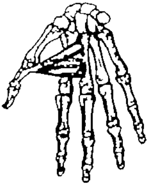

FIG 716

The middle palmar space is separated from the thenar space by a fascial septum which is attached with the adductor pollicis to the middle metacarpal.

When the middle palmar space has become involved the general signs of infection are aggravated There is marked local tenderness in the palm and, while obvious bulging is prevented by

drains through the interosseus space between the fourth and fifth metacarpals when the ulnar bursa is involved and through the commissure of the thumb

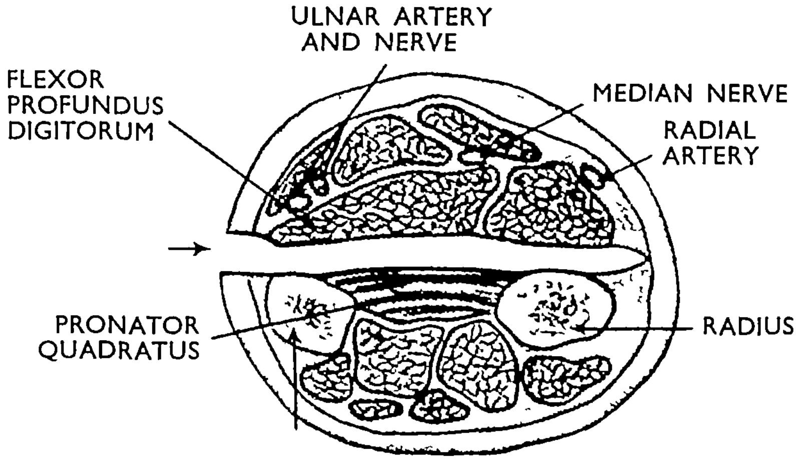

Fig 713

Anatomical plane for draining the proximal extremities of the ulna and radial bursæ

in infection of the radial bursa In Iselin's experience, adequate drainage of the sheaths is ensured by these incisions, and in the great majority of cases it is unnecessary to divide the anterior annular ligament The prognosis depends less on the length than on the site of the incisions The pus collects in certain well-defined areas it must be sought there, and there only, and long incisions become useless

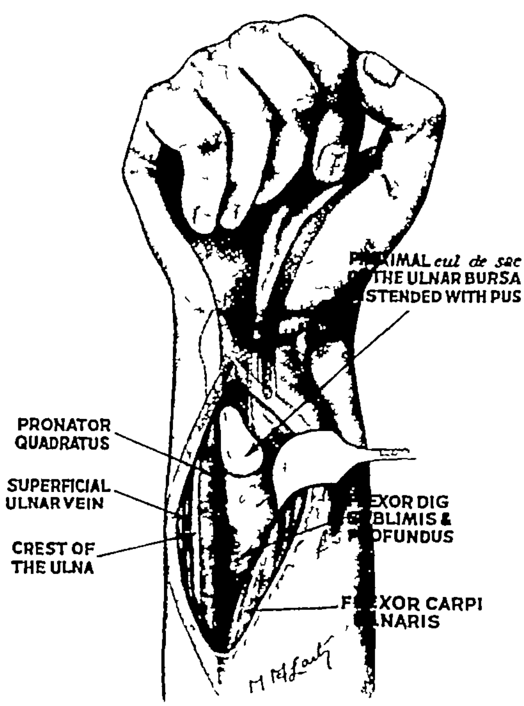

Fig 714

The forearm incision to expose the ulnar bursa (*After Iselin*)

The ulnar incision to drain the proximal extremity of the ulnar bursa and any extension to Parona's space is made as follows From a point about an inch above the lower end of the ulna a 3-in incision is carried upwards over the easily palpable border of the ulna, and deepened down to the bone slightly on to its flexor surface The aponeurosis between the tendon of the flexor carpi ulnaris and the anterior border of the ulna is divided and the tendon is retracted forwards The space is opened up by inserting and separating the blades of a hæmostat, exposing thereby the pronator quadratus which can be recognized by the transverse direction of its fibres That the correct plane (Fig 713) has been entered is evident because the finger can be passed without

it through the web distal to the important branch which is given off from the lateral division of the median nerve to the short muscles of the thumb opposite the middle of the metacarpal of the thumb (Fig 719)

INFECTIVE ARTHRITIS

Infection of a joint is often difficult to diagnose when it occurs during treatment of an infected wound or complicates an infection of the tendon sheaths

Phalangeal joints—The interphalangeal joints may be infected by wounds particularly of the dorsal aspects of the fingers but the most common cause of infective arthritis of the proximal interphalangeal joints is suppurative digital tenosynovitis In the latter osteomyelitis often develops and the functional outlook is hopeless Disarticulation should be performed at the metacarpo-phalangeal joint because of the infection in the tendon sheath rather than the arthritis An infection commencing in and restricted to the proximal interphalangeal joint may be treated in its acute stage by resection of the head of the proximal phalanx if conservative treatment fails The same operation may also be indicated after the infection has subsided if the joint has been allowed to become ankylosed in extension

When the arthritis affects the thumb even though it be accompanied by tenosynovitis of the long flexor one must be as conservative as possible and try by draining the sheath and resecting the joint to save the thumb

Metacarpo-phalangeal joints—The metacarpo phalangeal joints are most often infected as in the formidable bite injuries of civil life by wounds of the knuckles of the clenched hand which so readily sever the subcutaneous extensor tendons stretched over the heads of the metacarpals The joint involvement is often not detected till the signs of infection appear Aspiration immobilization in flexion in plaster and sulphonamides may then cause the arthritis to subside if not it may become necessary to provide free drainage by resecting the head of the metacarpal

The wrist joint—Infection of the wrist joint (see Chapter LXI) is a not infrequent complication of severe wound infections of the hand particularly following suppuration in the radial and ulnar bursæ

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the dense palmar fascia, the central hollow is obliterated General swelling and, in particular, œdema of the back of the hand are greatly increased as the infection develops

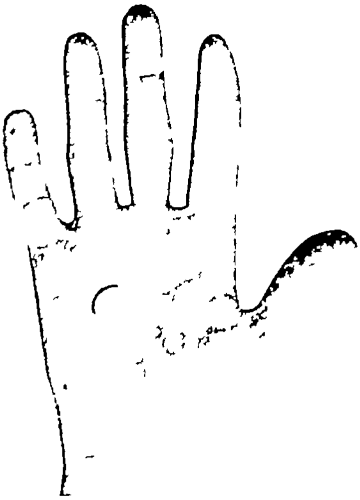


Fig 717
Bunnell's incision for draining the middle palmar space

Iselin emphasizes that pus in the middle palmar space always signalizes its presence by paralysis of the interossei These muscles lie immediately under the pus and are therefore picked out and remain paralysed for a long time After the period of suppuration, trophic troubles of the finger also become manifest as a result of irritation of the nerves and vessels in their palmar course

The usual practice in former years was to drain an abscess in the middle palmar space through a vertical incision in line with the ring finger, but since Bunnell has emphasized the objection of contracture resulting from a vertical scar in the palm, this space is now generally drained through a curved transverse incision just beneath the distal flexion crease of the palm (Fig 717), great care being taken to avoid opening the ulnar bursa Through this incision is passed the point of a hæmostat The jaws are opened and a strip of corrugated rubber is introduced

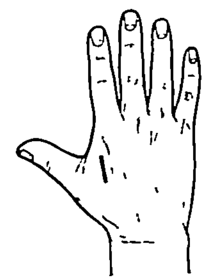


Fig 718
Kanavel's incision for draining the thenar space

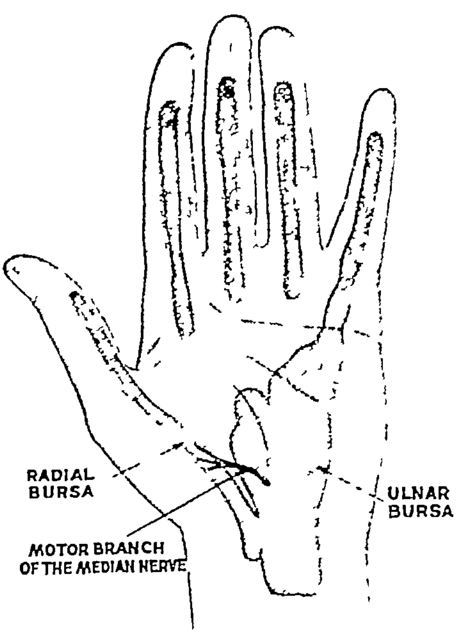


Fig 719
Relation of the motor branch of the median nerve to the radial bursa

The thenar space contains the thenar muscles An abscess in this space presents no difficulty in diagnosis, for there is obvious ballooning of the thenar eminence Involvement of this space is usually secondary to suppurative tenosynovitis of the flexor pollicis longus It may also result from direct infection through a wound of the web or more rarely follow infection of the sheath of the index finger

The pus surrounds the adductor muscle and the abscess may be drained, either as Kanavel recommends, by an incision made on the dorsal surface of the thumb-index web, or by the through-and-through incision through the web The Kanavel incision (Fig 718) avoids a scar on the palm, and is made at the middle of a line between the distal ends of the metacarpal bones of the thumb and index finger

If the through-and-through incision is used, care must be taken to make

Immobilization—In all stages after the wound toilet the foot must be immobilized in plaster of Paris or a splint The fixation must hold the foot at right angles to the line of the leg with neither inversion nor eversion The internal longitudinal arch must be supported and there must be firm support on the plantar surface of the metatarsal heads so as to prevent clawing of the toes Neglect of this simple precaution may lead to severe contractures which may be extremely difficult to correct The simplest and most efficient splint is a half leg plaster of Paris cast (Fig 720) To prevent any danger to the circulation when the foot is encased in plaster the cast is immediately split along its whole dorsal surface and the limb elevated on pillows or a Braun's splint

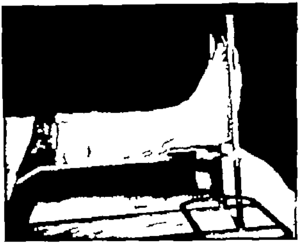


Fig 720

Half leg plaster Fracture of all metatarsals. The plaster is split along its length and the limb elevated on a Braun's splint.

In the absence of a persistent rise of temperature or of discomfort in the foot the plaster remains in position for two weeks and is then removed the wound inspected and if necessary a new cast applied after dressing the wound This procedure is repeated at intervals until healing is complete

When infection supervenes—Rise of temperature with discomfort in the foot and tenderness and swelling of the inguinal glands is an indication for immediate removal of the cast and inspection of the wound Such symptoms indicate failure of the attempt to avoid infection All the stitches should be removed and incisions made so as to drain the wound freely Drainage is maintained by a light vaseline pack and a new cast is applied which is renewed from time to time until healing is either complete or is sufficiently advanced for *skin grafting*

The above principles are applicable to all wounds there are however some rules which apply only to foot injuries and these are founded upon the physiology of the foot

THE FOOT AS A WEIGHT BEARING STRUCTURE PRINCIPLES UPON WHICH TREATMENT IS FOUNDED

In standing, the body weight is balanced upon the astragalus and from there transferred to the heel and fore part of the foot. Approximately half of the standing weight in low heeled shoes is transferred to the heel and of the remaining half the greater part is taken by the first metatarsal head and the rest by the outer four metatarsals, each of which is in contact with the ground. The whole of the fore part of the foot serves to increase the base upon which the body is balanced.

The whole body weight falling upon these areas requires the presence of a rigid system connecting the weight-bearing surfaces to the astragalus. This is provided by the peculiar shape of the tarsal bones which rigidly lock together into a system of arches, the lock being maintained by the position of the ligaments and the postural tone of the muscles. The muscles do not in any sense support the arches, but serve to balance the weight upon the arches. The key of the arch system and of the rigidity of the weight bearing foot is the mid tarsal joint

The fixed, rigid foot of static weight-bearing changes to a mobile appendage during locomotion

CHAPTER LXVII

WOUNDS OF THE FOOT

WAR injuries to the feet are produced either by projectiles or by crushing The heavy boots worn by soldiers are no protection against missiles, but they may save the foot some damage from compression The slight protection afforded by the boot does not outweigh the disadvantage that foot coverings are usually dirty, especially in war, with the result that wounds are frequently contaminated with fragments of boot and sock, this greatly adding to the probability of infection

The bones of the foot are but thinly covered with soft tissues, so that wounds almost always result in severe compound fractures with considerable comminution of the bones and much destruction of tissue, again making infection more likely

These facts explain the frequency with which foot wounds become infected, and emphasize the necessity for particularly attentive treatment

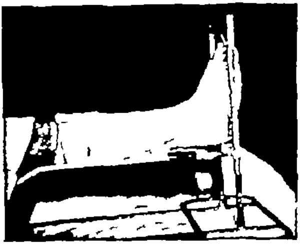
WOUNDS SEEN WITHIN TWELVE HOURS OF INJURY—As elsewhere in the body, all wounds, if seen within twelve hours of the injury, must be excised most thoroughly Bleeding vessels are picked up with hæmostats, and these are left on until the excision is completed If this is done, ligatures are usually unnecessary, except for the larger arteries which are tied with fine catgut When the excision is complete, an attempt must be made to close the skin over the wound The skin alone is sutured and no attempt is made to join deep structures, as any buried suture material undoubtedly increases the liability to suppuration, and any necessary reparative surgery can be carried out more easily and safely when the wound is healed and all danger of infection over

The skin must be closed without tension, as any tension on the wound edges will invariably result in sloughing and infection If suture without tension is impossible, then either relaxing incisions must be made so as to swing primary flaps over the wound, or the wound must be left open without sutures It is particularly important to close wounds of the sole, since large granulating areas in this weight-bearing region often result in painful scars which necessitate subsequent excision and skin grafting, a procedure which may present considerable difficulty and does not give such good results as primary suture

WOUNDS SEEN MORE THAN TWELVE BUT LESS THAN TWENTY-FOUR HOURS AFTER INJURY must be excised carefully and the wound left open

WOUNDS SEEN AFTER TWENTY-FOUR HOURS are treated by débridement (see Chapter XI), no attempt at formal excision is made, but the wound is enlarged so as to ensure free drainage of all pockets The wound is then left wide open and packed lightly with vaselined gauze

Immobilization—In all stages after the wound toilet the foot must be immobilized in plaster of Paris or a splint The fixation must hold the foot at right angles to the line of the leg with neither inversion nor eversion The internal longitudinal arch must be supported and there must be firm support on the plantar surface of the metatarsal heads so as to prevent clawing of the toes Neglect of this simple precaution may lead to severe contractures which may be extremely difficult to correct The simplest and most efficient splint is a half leg plaster of Paris cast (Fig 720) To prevent any danger to the circulation when the foot is encased in plaster the cast is immediately split along its whole dorsal surface and the limb elevated on pillows or a Braun s splint



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The fixed, rigid foot of static weight-bearing changes to a mobile appendage during locomotion

The body-weight is levered by the pull of the calf muscles on to the metatarsal heads, and during this action there is considerable dorsiflexion of the toes at the metatarso phalangeal joints Movements also occur at the tarsal joints, but walking can be performed comfortably and well with the whole tarsus rigid, provided the metatarso-phalangeal joints are free The essentials, therefore, for a useful foot are stability of the tarsus and mobility at the metatarso phalangeal joints

From a consideration of these facts it becomes clear that in injuries of the foot treatment must be designed to preserve, as far as possible, the normal weight-bearing areas, the stability of the tarsus and the mobility of the metatarso-phalangeal joints

Preservation of function is a cardinal consideration—The weight-bearing areas are of importance in this order the heel, the first metatarsal and the outer four metatarsals Loss of any two of these areas is incompatible with painless weight-bearing and is therefore an indication for amputation Loss of one of the two major areas, the heel or the first metatarsal, will in all probability lead to a painful foot and may require amputation in order to give the maximum function (Fig 721)

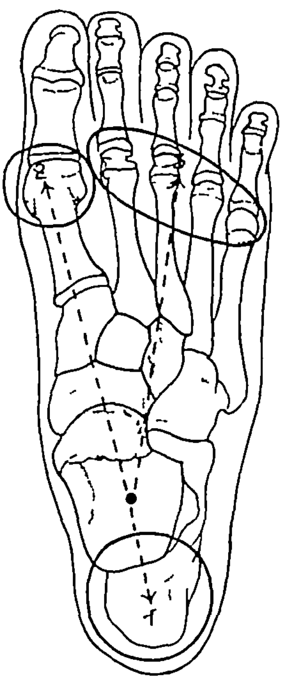

Fig 721
The weight is distributed from the astragalus to areas 1, 2 and 3 Loss of any two of these is an indication for amputation

The rigid system of the mid-tarsal area must be preserved, for mobility of this region is not necessary for walking, and stability is essential if weight-bearing is to be painless Therefore, mid-tarsal injuries leading to joint destruction are often best treated by late mid-tarsal arthrodesis, thus exchanging the natural lock of bone surfaces for the artificial lock of bony ankylosis

The mobility of the metatarso-phalangeal area must be preserved, particularly of the first metatarso-phalangeal joint, otherwise the leverage action of walking will be impossible The toes are of decreasing importance from the great toe outwards

Careful attention to these general principles will simplify treatment considerably, for example, the amputations of Lisfranc and Chopart have no place in the treatment of foot injuries, for they violate the first principle, that at least two of the weight-bearing areas must be intact for painless weight-bearing If amputation is considered necessary, then, except for amputation of the toes, the whole foot must be removed either by Syme's amputation or by amputation at the site of election in the leg

WOUNDS IN VARIOUS PARTS OF THE FOOT

Wounds of the toes—Wounds of the toes almost always result in compound fractures of one or more phalanges The great toe is of immense importance for the satisfactory functioning of the foot, and therefore every effort must be made to preserve it, indeed, the great toe is of more importance than all the other toes put together Movement at the metatarso-phalangeal joints is also of great importance, as, with ankylosis of these joints, painless walking is impossible Treatment must therefore be designed to preserve as much as possible of the great toe and the mobility of the metatarso-phalangeal joints Loss of mobility of the interphalangeal joints is of little consequence, indeed, ankylosis of these joints is not

followed by any disability Compound fractures of the distal or proximal phalanges must be treated by immediate excision of the wound and suture if possible followed by elevation of the foot until the wound is healed Then a collodion gauze dressing or strapping is applied and weight bearing allowed in a boot with the toe-cap cut out and a metatarsal bar screwed to the sole (Fig 722) Extensive damage to the metatarso phalangeal joint of the great toe frequently produces a severe degree of hallux rigidus Resection of the base of the proximal phalanx then becomes necessary (Keller's operation) The results of this operation are very good provided sufficient of the phalanx is removed—at least half should be resected and the divided end smoothed off carefully (Fig 723)

FIG 722

Bar fixed to the sole behind the heads of the metatarsal bones.

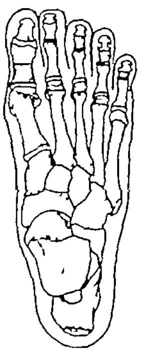

FIG. 723

Skeleton of the foot showing the amount of bone removed in Keller's operation.

Severe damage to the toes except the first is best treated by amputation at the metatarso phalangeal joints These cases are frequently complicated by injury to the metatarsal heads often with extensive loss of skin The skin of the damaged toes can often be preserved and used as flaps to cover denuded areas in the region of the metatarsal heads This is an extremely valuable procedure as it frequently enables the whole metatarsal region to be preserved and covered with skin at the primary operation More formal amputation of the toes at the metatarso-phalangeal joint is carried out with a large plantar flap

Metatarsals—Compound fractures of the metatarsals produced by projectiles are often associated with gross fragmentation and excessive loss of tissue When produced by crush injuries considerable displacement may occur and the injury is frequently associated with swelling of the whole foot Excessive damage of this type may render precarious the blood supply of the distal part of the foot and toes and in these injuries the circulation of the toes must be watched most carefully

Displacement in metatarsal fractures must be corrected especially in the first metatarsal and in fractures of the metatarsal heads, as persistent displacement frequently leads to pain on weight bearing Great care must be taken in choosing the time for reduction as if powerful traction and tight plasters are applied to a greatly swollen foot with doubtful circulation gangrene is likely to supervene For this reason it is inadvisable to attempt correction of the displacement until the swelling has subsided for not only is there danger of circulatory disturbances but accurate fixation of the fractures is impossible in a greatly swollen foot The usual excision is therefore carried out the fractures manipulated into as good position as possible and the foot immobilized in a plaster cast which is immediately split throughout its whole length The whole limb is then elevated on pillows or a Braun's frame When swelling has subsided—usually after about seven days—and all danger to the circulation is passed the displacement

is reduced by powerful traction upon the toes and the position maintained by fixation in a non-padded cast well moulded to the arch of the foot and supporting the plantar surface of the toes

Displacements which tend to recur, or cases in which there has been considerable loss of tissue, can be maintained in position by continuous traction by means of a stainless-steel stirrup passed through the pulp of the toe and fixed by tapes to a banjo splint incorporated in the plaster This traction is maintained for three weeks, after which a new moulded cast is applied and weight-bearing allowed Fractures of the metatarsals are immobilized for six to eight weeks in all, and after removal of the plaster it is advisable to fit an arch support for four to six months

Dislocation of one or more metatarsals at the tarso-metatarsal joint may occur Immediate reduction is effected by strong screw traction applied through stirrups passed through the pulps of the toes, counter-traction being maintained by an os calcis pin The cast must be immediately split, for there is considerable danger to the circulation Immediate reduction is necessary in this injury as any considerable delay may result in great difficulty in subsequent reduction Fixation is maintained for eight weeks in a non-padded cast, walking being allowed after two to three weeks

Tarsal bones—Penetrating wounds of the tarsal region frequently cause extensive comminution of the bones, after which restoration of the normal anatomy is impossible In these cases the object must be to restore the shape of the foot as far as possible, bearing in mind that rigidity of the tarsus is essential for proper weight-bearing If the loss of tissue is so great that restoration of stability of the tarsus is impossible, or if, as is frequently the case, the circulation of the distal part of the foot is impaired, then amputation at the correct level is the best treatment

Severe crush injuries to the tarsus are also frequently complicated by such damage to the blood vessels that gangrene is inevitable, here also, amputation is the correct treatment

In penetrating and crush injuries not complicated by severe vascular damage, the wound is treated on general lines and the tarsus then moulded into shape as far as possible and a plaster applied The cast is immediately split throughout the whole length and the limb elevated on a Braun's frame After fourteen days, when the swelling has subsided, further moulding is carried out and a new cast applied, accurately fitting the foot This cast is kept on for four months, weight-bearing being allowed after four weeks Before the cast is finally discarded, X-ray evidence of sound union of the fragments must be obtained

Often, however, in spite of this treatment, the foot remains weak and unstable, the arch flattening and the foot falling into severe valgus position, resulting in pain and swelling on weight-bearing Carefully fitted arch supports and strong, well-designed shoes may do much to alleviate the disability, as also may the wearing of an outside iron and inside T-strap, but should these measures fail, operative arthrodesis of the affected joints should be performed Naughton Dunn's operation of mid-tarsal and sub-astragaloid arthrodesis with backward displacement of the foot, or some modification of this to suit the individual case, is the operation of choice Cases in which there has been much bone destruction cannot be given a stable

foot by any of these means, and amputation is then the best treatment I have frequently had patients ask for amputation after prolonged con servative treatment which whilst saving the foot had failed to restore stability in the tarsal region

Less severe injuries to the tarsus consist of fractures and fracture dislocations of isolated tarsal bones

Scaphoid, cuboid and cuneiforms—Displacement in these bones must be corrected as far as possible for stability of this region is essential for painless weight bearing Reduction is effected by powerful traction and moulding Traction is obtained by similar methods to those used for the metatarsals and the same precautions against swelling must be observed—that is the cast must be split and the limb elevated A new moulded plaster is applied after three weeks and the cast retained for ten to twelve weeks in all weight bearing being allowed after four weeks

Astragalus—Injuries to this bone are serious for its articulations viz the ankle-joint the subastragaloid joint and the mid tarsal joint are particularly im portant Arthritis of any of these joints the result of malalignment of fractures of the astragalus seriously disturbs the functions

FIG 724

Foot after astragalectomy The astragalus had been torn out through a lacerated wound, the scar of which can be seen over the outer malleolus.

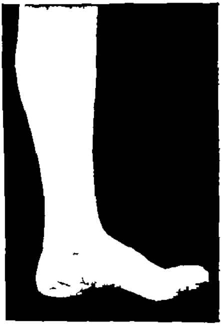

FIG 725

Foot after astragalectomy The bone was protruding through a wound on the inner border of the foot.

of the foot by interfering not only with the stability of the foot but also with the mobility of the ankle-joint

Gross destruction of the astragalus is best treated by astragalectomy with backward displacement of the foot This operation gives surprisingly good functional results (Figs 724 and 725) and is certainly preferable to a foot with extensive arthritis of the astragaloid joints

In destruction of the head of the astragalus alone after healing is obtained a Dunn fusion may be carried out with good prospects of sound function

Fractures of the astragalus without gross destruction should be immobilized in plaster for three months X ray evidence of union being obtained before fixation is finally discarded

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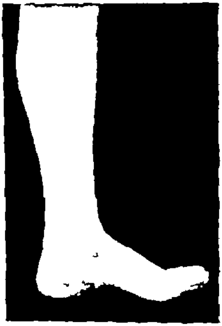

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Subastragaloid dislocation of the foot either medially or laterally, with or without fracture of the astragalus, occasionally occurs The medial dislocations are easily reduced by traction with the knee flexed The lateral dislocations may be more difficult, open reduction is sometimes necessary, as the tendons on the inner side become displaced round the neck of the astragalus, and present an insuperable barrier to manipulative reduction When reduction has been effected, the foot is immobilized in plaster for eight weeks The results are good provided accurate reduction has been obtained

Os calcis—Comminuted fractures of the os calcis with extensive bone

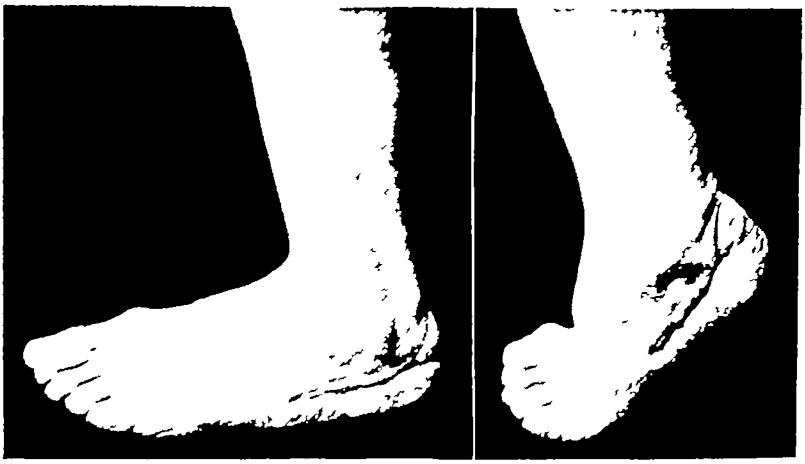

FIG 726

Foot after loss of almost the whole os calcis

FIG 727

X-ray of case illustrated above

destruction are extremely serious The loss of one of the main weight-bearing bones frequently results in a painful, useless foot, though occasionally, in spite of loss of bone, a good weight-bearing foot is obtained (Figs 726 and 727) This is more likely if the subastragaloid joint has been spared, as in injuries of the tuberosity (Figs 728) Involvement of the subastragaloid joint usually results in a severe arthritis which is extremely painful In cases of compound fracture, after routine treatment of the wound the os calcis is moulded into as good a position as possible by manipulation and a plaster applied. After healing of the wound has been obtained, subsequent treatment must be guided by study of good X-rays taken in the lateral (Fig 729) and dorsi-

plantar planes If the displacement can be reduced by the standard screw traction method (Böhler) this is carried out but should the sub astragaloid joint be severely involved as is always the case with extensive comminution of the body of the bone then arthrodesis of the sub astragaloid and mid tarsal joints gives the best chance of a satis factory result

Simple fractures of the os calcis sustained by falls from a height or blows upon the heels are treated by the standard methods of reduction (Böhler Watson-Jones) but here also if the joints are involved subsequent mid tarsal and sub astragaloid arthrodesis are often necessary

Fig 728

Foot after loss of the tuberosity of the os calcis. The patient is standing with the whole weight on the toes

Fig 729

X ray of case illustrated above

INFECTED WOUNDS OF THE FEET

Many wounds of the foot are first seen long after that period in which primary excision can be carried out with prospect of suc cess moreover even in favourable cases suppuration may follow primary excision In any case free drainage of the fascial spaces of the foot must be obtained im mediately There are three main fascial spaces in the sole—a medial a lateral and a central—and as in the hand suppuration remains confined to

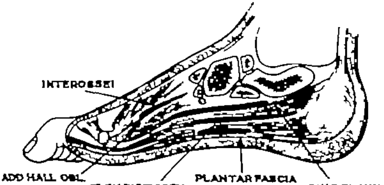

Fig 730

Sagittal section between the second and third metatarsal bones, showing fascial spaces. (*After Grodinsky*)

these for some time The medial and lateral spaces communicate round the sides of the foot with the dorsal fascial space whilst the central compartment divided into four sections by the muscular layers of the sole (Fig 730)

communicates through the inter-metatarsal spaces with the dorsum. Any or all of these spaces (Fig 731) may become infected in penetrating injuries,

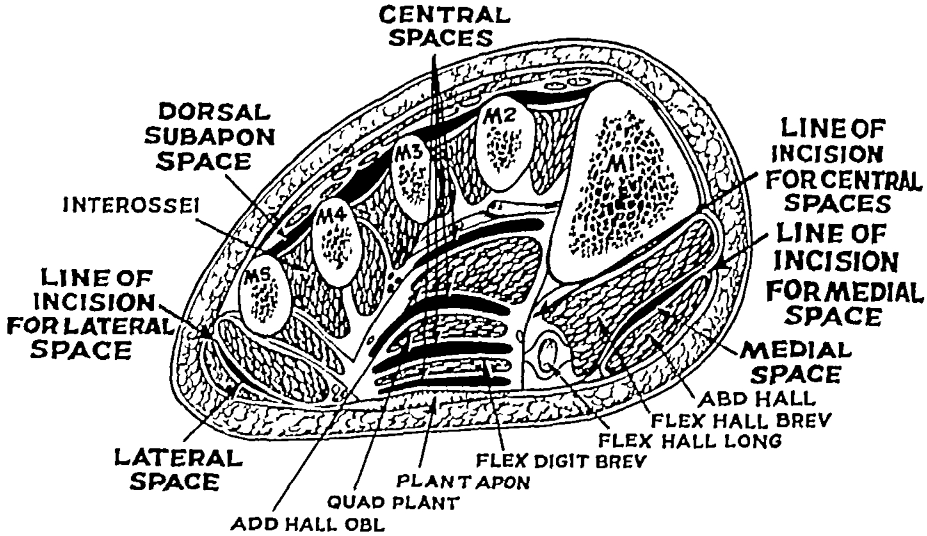

Fig 731

Transverse section through the middle of the metatarsals, showing fascial spaces The line for opening the lateral, medial and central spaces is shown. Note particularly that the four central spaces can be opened by the same incision if the fascial septum is penetrated (*After Grodinsky*)

and the infection in all cases will tend to spread either to the lateral border of the foot or to the dorsum, or both

Involvement of tendon sheaths in the sole is not nearly so important as in the hand, for the fine movements of the fingers, lost after suppurative tenosynovitis of the palm and resulting in severe loss of function, cannot be compared with similar loss in the toes, where no fine movements are necessary for satisfactory function

Infection in the bones of the feet following compound fractures is usually extensive The close proximity of the bones and their joints often leads to a rapid spread of infection, and in these cases, as in all others, adequate drainage is the best safeguard against spread of infection

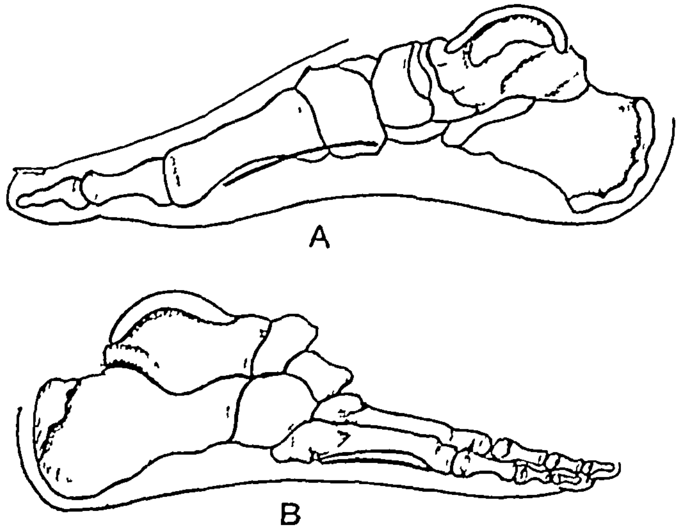

Fig 732

A, Line of incision for drainage of both the medial plantar and the central plantar surfaces
B, Line of incision for drainage of the lateral space

The necessary incisions for drainage in infection of the sole are best made with safety at the lateral and medial borders of the foot, for not only is adequate drainage obtained (Fig 732) but the subsequent scar is away from

weight bearing areas Frequently however sufficient drainage can be obtained through the original wound Infection in the sole should never be *drained through the dorsum between the metatarsals* (Hauser)

After providing free drainage for all infected areas the wounds are packed lightly with vaselined gauze and a plaster applied the cast being immediately split and the limb elevated on pillows or a frame Fixation in a plaster or splint is most important as otherwise severe contractures may occur resulting in considerable deformity of the foot most difficult or even impossible to overcome

The sulphonamide drugs should always be given as prophylaxis against infection in wounds and should be given in maximum dosage in all cases of established infection

In the presence of infection attempts at reparative surgery or reduction of displaced fractures should not be made for the additional trauma will *inevitably lead to spread of the infection possibly with disastrous results* When infection has supervened in cases where the fracture has already been reduced then every effort must be made to maintain the position for continued immobilization is of benefit both to the fracture and the infection Therefore provided adequate drainage can be established fixation should be maintained This ideal however is frequently impossible in the foot

LOSS OF TISSUE METHODS OF REPAIR

Loss of skin is a frequent difficulty especially when occurring on the sole If large wounds of the sole heal by granulation, the subsequent scars are often so tender as to be disabling whereas scars of the dorsum rarely give rise to such difficulties Wounds of the sole should therefore if possible be covered by flaps turned from the side or dorsum of the foot by relaxing incisions Subsequently the denuded areas thus formed can be covered by skin grafting

Skin grafting to the weight bearing areas must be with full thickness grafts either free or pedicled from the opposite thigh The grafts must be cut with care to suit each individual case As previously mentioned *damaged skin on the distal part of the foot can often be replaced by that* saved from injured toes and surprisingly large areas can be covered by this expedient

AFTER-TREATMENT IN WOUNDS OF THE FEET

The treatment of the more severe tarsal and metatarsal injuries involves fixation in plaster for a number of weeks As a result of this fixation and of the injury there is some muscular wasting and a tendency to œdema of the foot and leg when the plaster is removed Both the muscle wasting and the œdema can be minimized by walking in the plaster thereby exercising the calf muscles during the period of immobilization This exercise is however not sufficient to maintain full muscle tone and in severe injuries walking is only possible for a part of the period of immobilization

The œdematous swelling which occurs after removal of the plaster may be very disabling for although it is not usually associated with much pain the increased size of the foot makes it impossible to wear a satisfactory shoe This swelling can be prevented by the application of an Unna s paste

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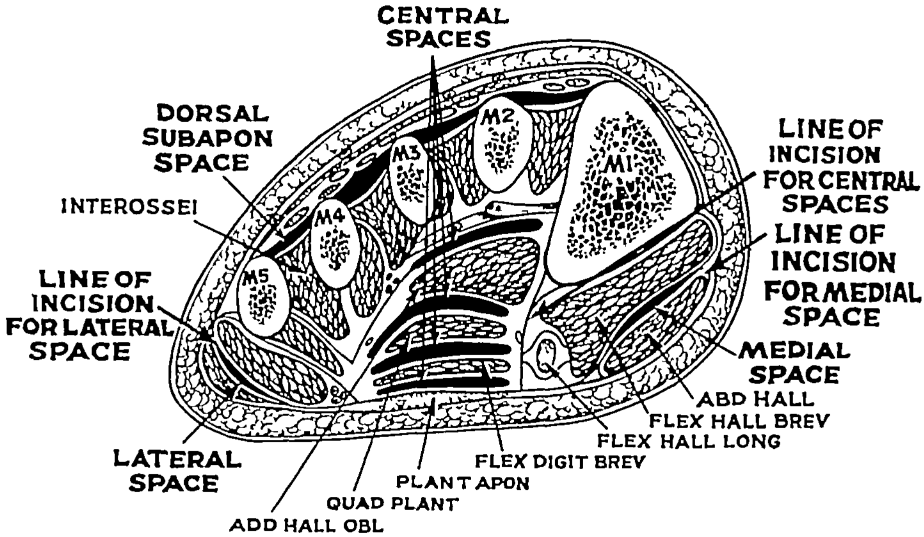

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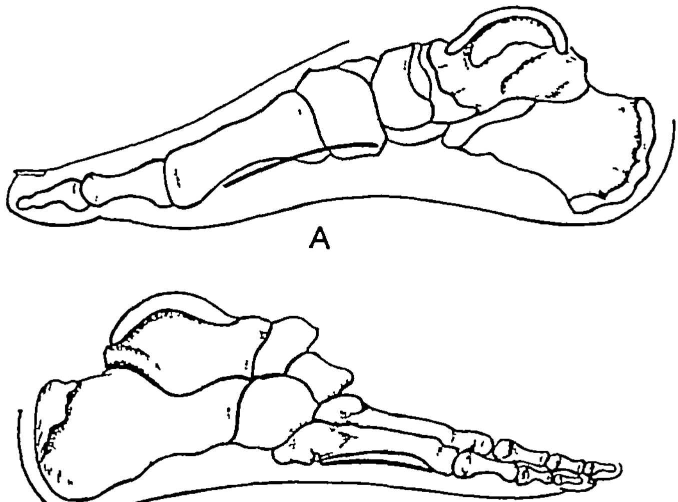

Fig 732

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B, Line of incision for drainage of the lateral space

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The necessary incisions for drainage in infection of the sole are best made with safety at the lateral and medial borders of the foot, for not only is adequate drainage obtained (Fig 732) but the subsequent scar is away from

Here an outside iron slotted into the heel, with an inside T strap together with an arch support (Fig 737) must be fitted to the shoe and worn for three months after which the arch support will be necessary for a further six months

These precautions against swelling and foot strain should never be neglected for with the foot properly supported in a satisfactory position the exercise obtained by walking will restore muscle power with great rapidity whereas if the foot is allowed to assume a valgus deformity, pain and wasting will persist in spite of massage and exercises and may eventually result in a painful rigid flat foot

After injuries involving the soft tissues of the sole tenderness on walking is sometimes experienced A soft felt in sole fitted in the shoe usually gives considerable relief It should be worn until the tenderness disappears

Fig 37
Shoe with outside iron and inside T-strap.

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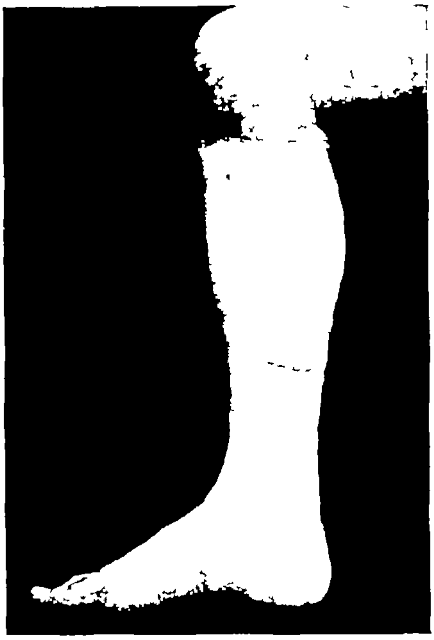

FIG 733
Unna's paste dressing

dressing to the foot and leg (Fig 733) immediately after removal of the cast The dressing must extend from the base of the toes to the tuberosity of the tibia, thus forming an elastic stocking which, by its firm support of the soft tissues, prevents œdema This should be kept on for six weeks, or longer if the tendency to swelling persists, being discarded only when there is no sensation of tightness after prolonged periods of standing or walking If the dressing becomes worn or dirty it should be removed and replaced

The loss of muscle strength and tone during immobilization frequently results in a painful foot strain, with eversion of the heel and flattening of the longitudinal arch when normal weight-bearing is resumed This foot strain is exactly similar to that which occurs on resuming weight-bearing after any prolonged or acute illness In order to avoid this complication, boots or shoes must be worn which hold the foot in a normal position and thereby prevent both eversion of the heel and flattening of the arch

FIG 734
Shoe with Thomas' heel

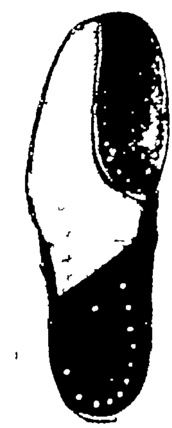

FIG 735
Shoe with Thomas' heel and inside lift to the sole

After the less severe injuries, all that is necessary is a firm shoe or boot fitted with a Thomas' heel which supports the shank of the shoe and tilts the heel into the normal position (Figs 734 and 735) This should be worn for four to six months

In more severe cases a properly moulded arch support made either of firm sorbo rubber or of metal covered with leather (Fig 736), should be fitted inside the shoe and worn for about six months

FIG 736
Arch supports The small support is made of rubber and stuck in the shoe The large support is of leather with a rubber pad and slips into the shoe

Occasionally the valgus position is so severe that these appliances are not sufficient to control the foot

SECTION XV

AMPUTATIONS

CHAPTER LXVIII

AMPUTATIONS

An amputation rendered necessary by war injuries may be an entirely different proposition to a planned operation for disease in times of peace. Bullets, bombs, shells, torpedoes and mines have no respect for anatomy, and the surgeon is faced with problems requiring promptitude, originality and skill. As a basis for modified and *ex tempore* emergency procedures, well known types of amputation will be outlined in this chapter.

A golden rule is that too low an amputation can be remedied, too high removal of a limb is beyond repair.

FUNDAMENTAL PRINCIPLES

Should prior consideration be given to stereotyped protheses?—The surgeon must have an eye to the future and strive, usually by a conservative route, to pilot the patient to the goal of maximum function. Regard for the dictates of the limb maker is all to the good, and co-operative work is essential for success. On the other hand, surgeons must avoid a mass production mentality when engaged in the manufacture of stumps.

Standardized and easily produced protheses must receive consideration, but they should not prejudice the surgeon's judgment unduly in deciding at what level to remove a limb. The writer was on the staff of a hospital for the limbless and for the supply of artificial limbs, and was a member of the joint committee of surgeons and limb-makers during and after the 1914-18 war. He came to the conclusion that the amputation level favoured by the limb-makers were not always those which provided maximum function. The majority of war victims are vigorous young adults. In these patients stumps, far from ideal as judged by usual standards, may function in an exemplary manner.

In war time limb-makers, like others, putting pride before profit, can by ingenuity and care overcome the difficulties of fitting an unorthodox stump. Elmslie, who was a foremost authority on amputations, sounded useful warnings at the termination of the last war. He wrote convincingly on the fallacies of hide-bound teaching in connection with "seats of election." This warning was echoed in 1938 by Oppenheimer, who said: "Many amputees exist with tissue which is of value to them but a problem to the brace-maker. That is no reason why tissue should be sacrificed." The article goes on to say that there are many ways of overcoming these difficulties: "double sockets, double joints, hand made braces, moulded composition parts, and combination weight bearing."

The old general rule of sacrificing as little of the limb as possible still holds good, with a few notable exceptions.

When ligature in continuity above the site of proposed amputation is necessary.—In most cases it is better to ligate both the artery and the vein; the vein is omitted only if a good collateral circulation is established already. When feasible, resection of a small segment of the artery is better than simple ligature; by resection the periarterial sympathetic fibres are extirpated, and this extirpation favours transient dilatation of the collateral arterial branches below.

Dealing with large nerves—The question of how to deal with divided nerves is still unsettled The writer pulls them down gently and injects a local anæsthetic above before crushing and ligature One of the best local anæsthetics with prolonged action is well heated proctocain Forcible dragging on large nerve trunks is condemned It is believed by some that the crushing and ligature designed to prevent the riotous spread of axis cylinders is not justified and that the nerves do best when they are left alone after their simple division The majority of surgeons favour shortening of nerves and this has been carried out over a period of many years in all parts of the world *with satisfactory results*

Drainage—In badly infected cases the wound after amputation should be left wide open Many clean cases can be closed without drainage if hæmostasis is satisfactory

Dressings—A large gauze dressing covered by several superimposed thin layers of wool is held in place with an elastoplast bandage The latter is applied tightly over the wool The entire stump is then encircled with plaster of Paris bandages

FIG. 740

Secondary below knee amputation with plaster applied to stump. Plaster was not used following the primary amputation at a lower level Troublesome flexion of the knee has resulted.

Plaster of Paris—Curiously enough in these days of enthusiasm for the plaster of Paris immobilization of limbs little has been said about its advantages when applied to the stump immediately following amputation The writer employs it as a routine The patient feels a sense of comfort and protection which no other dressing or appliance supplies A plaster cast appears to lessen phantom pains and it prevents flexion of the joint above The mere weight of the plaster in amputations at or below the middle of the thigh prevents that tilting forward of the stump which later is such an embarrassment to the fitter of the artificial limb Furthermore immediate encasement encourages shrinkage and the stump is hurried to its final state Except in high amputations of the thigh it is unnecessary to include the pelvis and hip-joint in the plaster (Fig 740) Oozing of blood through the plaster is seldom an indication for its removal In amputations of the leg inclusion of the knee for the first week or ten days is desirable Flexion of the knee following these amputations may be a very troublesome complication It is prevented by plaster fixation

When the stitches are removed a skin tight plaster should be applied to the stump but not to the joint above if this can be avoided. Early movement of this joint is most desirable

By immediate encasement but early removal of the plaster the stump is hurried through the stage of shrinkage to its final state of muscular development and free joint movement

Preferable sites for the cutaneous scar—A terminal scar is satisfactory in the upper extremity A posterior scar is more favourable in the lower extremity There is little or no end thrust brought to bear upon an upper extremity stump, while in the lower limb there is usually some pressure on the end and lateral pressure is at a minimum When walking, the appliance has to be lifted forward, this brings some pressure and friction on the front of the stump, hence the desirability of a posterior scar If the skin flaps have been made too long in the first instance, they should be trimmed until they fit snugly Loose tissue persists more than is generally realized

Division of muscles—Covering the ends of divided bone with muscle, except in the case of the thigh is seldom necessary or desirable Muscle so placed soon becomes fibrous tissue and sometimes becomes adherent to the bone end On the other hand, retraction of the muscle far beyond the level of bone division is undesirable Such retraction may result in a long conical stump It is sometimes possible to raise flaps of deep fascia and to stitch these over the bone ends and so prevent excessive retraction of the general muscular mass

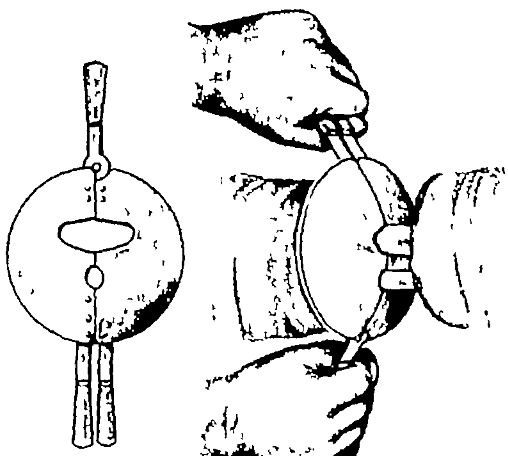

Fig 738
Didier's retractor

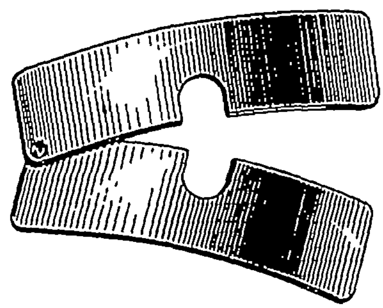

Fig 739
The Newcastle type of thigh amputation retractor

Sectioning the bone—Reflecting periosteum up or down is unnecessary; it is divided in circular fashion at the level of bone section Clean transverse section of the bone is made with a sharp saw The soft tissues must be retracted during this division Two excellent types of retractor are shown in Figs 738 and 739

"The Newcastle pattern of retractor consists of two concavo convex oblongs of $\frac{1}{8}$ in thick sheet copper hinged by a brass screw In the centre of a free edge of each oblong is a half circle aperture Each oblong measures $11\frac{1}{2}$ in long by $2\frac{1}{2}$ in wide, while the complete gap when the two sections are approximated makes a circle of 1 in diameter Near the aperture edge of each portion is a hole to take a small brass bolt screw and cap, this forms a loose hinge for the retractor" (Professor Willan)

A file is used to smooth the bone end At all times the soft tissues must be protected from bone dust, this is accomplished automatically by employing a retractor of the type indicated The cut end of the bone should not be covered with periosteum By taking these precautions the formation of irregular bony spurs may be avoided

AMPUTATION THROUGH THE UPPER ARM

In these amputations the aim should be to cover the stump with skin alone The length of the normal humerus in an adult averages about 12 in The seat of election for bone division is usually given as the junction of the lower with the middle third In other words the aim should be to save 8 in of the shaft The measurement is made from the tip of the acromion It has been found however that division at a lower level i e 2 or 3 in above the elbow joint instead of 4 has some advantages It carries the prosthesis equally well and there is increased leverage and strength

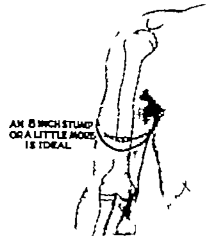

Fig 742
Incision for amputation through the upper arm.

Position—The arm is abducted when making the anterior incision and held vertically or drawn across the chest for the posterior incision

Operation—Two small skin flaps are fashioned one in front and the other behind (Fig 742) If the amputation level is too high for the application of a tourniquet the vessels and nerves are exposed and dealt with through a short vertical

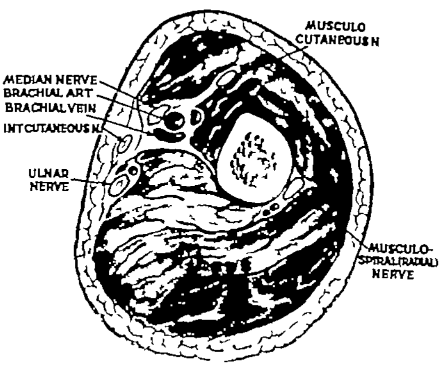

Fig 743
Transverse section through the upper arm.

THE UPPER LIMB

AMPUTATION AT THE SHOULDER-JOINT

If the head of the humerus is preserved, flattening of the shoulder and projection of the acromion are avoided If two or three inches of the shaft can be saved, the work of the artificial limb-maker is made less difficult Four inches of bone is the minimum for a stump of functional value If less than this, the prosthesis is purely ornamental

To control hæmorrhage the best plan is to expose and ligature the vessels as the amputation proceeds If in difficulties, pressure on the subclavian artery against the first rib may be applied by an assistant In applying pressure the fingers may become tired and a large padded key handle or similar device should be at hand In exceptional cases preliminary ligature of the subclavian artery may be required

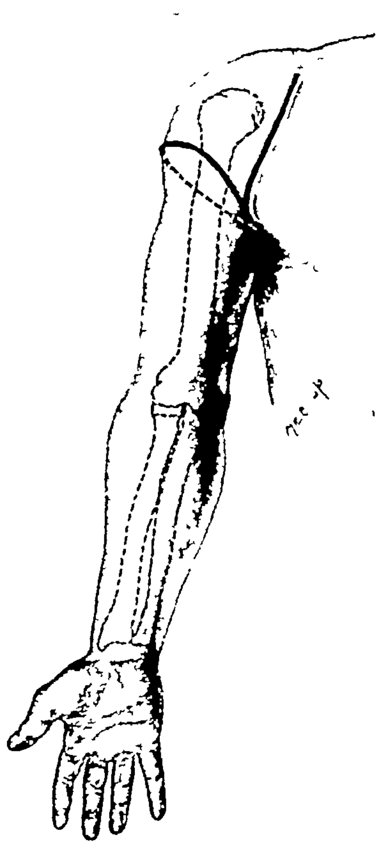

FIG 741
Incision for amputation at the shoulder-joint

Position—The arm is held abducted and rotated outwards

Operation—The incision is made from the coracoid process downwards as far as the lower limit of the anterior fold of the axilla Skin and fascia are divided and the incision carried outwards, over the deltoid to the posterior axillary fold It is then continued inwards and forwards in circular fashion to meet the original vertical incision (Fig 741) The inner flap of skin and fascia is reflected and the broad tendon of the pectoralis major muscle exposed The finger is passed under the muscle and the tendon divided At this stage little or no bleeding is encountered The pectoralis minor muscle is divided near its attachment to the coracoid process The axillary vessels and nerves are located, ligatured and divided at a high level Injection of the nerves with a local anæsthetic is a simple procedure in this situation The external skin flap is now raised and the deltoid is severed to the bone The muscle and skin flap thus formed can be lifted from the humerus without using the edge of the knife The joint is now exposed The muscles attached to the tuberosities are divided The supraspinatus, infraspinatus and teres minor are rendered tense by rotating the humerus inwards, and the subscapularis tendon is divided during external rotation Both heads of the biceps are severed in front of the joint The capsule is incised and the head of the humerus is dislocated forwards When possible, the head of the bone is left *in situ*, the humerus being divided at the level of the anatomical neck For division of the bone an electric saw or a Gigli's saw is recommended

upper portion is at the level of bone division the lower at a distance from the upper equal to the anteroposterior diameter of the limb After division of the muscles in circular fashion (Fig 746) the point of the knife is entered between the two bones to divide the interosseous membrane

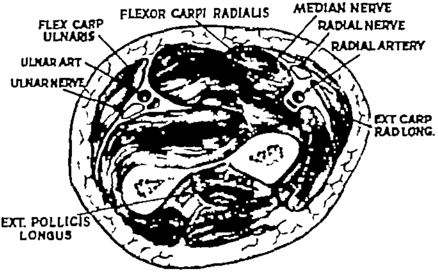

Fig 746
Transverse section through the forearm.

Both bones may be divided simultaneously with the arm in supination or if preferred the radius may be divided first and the ulna afterwards with the arm held in the mid position If the ends of the bones in the stump become united, supination and pronation are lost To prevent this the muscles of the front and back should be sutured together between the bones

AMPUTATION THROUGH THE WRIST-JOINT

The majority of surgeons have either not met with an injury in which this amputation was indicated or condemned it. On the rare occasions that no portion of the hand can be saved, and there is sufficient skin to provide a flap or flaps, the operation should be seriously considered. The writer has never performed the operation, but he has seen several satisfactory results.

The tendons are divided by circular division a little below the level of the joint line The wrist joint must be carefully located and opened from the radial aspect, otherwise the knife may be entered in error between the first and second rows of the carpal bones.

THE PRESERVATION OF THE HAND

Even in cases where all the fingers and thumb are hopelessly mutilated as much of the hand as possible should be preserved—The value of an amputation through or proximal to the metacarpal bones at any level far exceeds that through the wrist joint or forearm A movable stump distal to the wrist joint is a great functional asset (Fig 748)

To conserve portions of fingers and above all as much as possible of the thumb should need no emphasis There is a vast field for reconstructive surgery of the fingers and thumb To this end skin grafting tendon

incision The incisions then take the form of a racquet When the skin flaps have been raised, the muscles are divided in a circular fashion to the bone (Fig 743) The first sweep of the knife divides the triceps behind and the biceps in front When these have retracted, the deeper muscles are divided at the new level A Didier or other retractor is applied and the bone is severed with the precautions already mentioned

AMPUTATION THROUGH THE ELBOW-JOINT

Amputation through the elbow-joint is often rendered impossible by the nature of the injury, large flaps are required to cover the expanded lower end of the humerus To condemn the operation, however, is a mistake The limb fitters do not favour it As a matter of fact, if properly fitted, a more secure hold can be obtained for the artificial limb than is the case when an amputation is performed at a higher level

Position—The arm is slightly abducted and flexed to an angle of 130°

Operation—The most certain way of obtaining sufficient covering for the projections of the condyles is by the formation of a large internal and a short external flap Alternatively, the classical method of a long anterior flap and a short posterior flap may be employed Kocher recommended the racquet incision (Fig 744) in which the soft parts of the forearm are divided in circular fashion below the joint and the bones shelled out subperiosteally as far as the joint This is the most simple procedure In making a choice all will depend on the nature of the injury *To provide a long internal and short external flap,* a short vertical incision is made in the groove to the inner side of the prominence of the biceps tendon This exposes the brachial artery and the median nerve The nerve lies on the inner side of the artery, rarely behind it They are divided and ligatured in the usual way The incision is now carried in a curved direction downwards, backwards and finally upwards to reach the base of the olecranon process behind The skin and fascia are raised for ½ in and the knife is then carried to the bone A very short external flap is raised in a similar manner After division of the triceps tendon, the radio humeral articulation is defined and opened and the disarticulation is completed. The common error is not to provide enough flap for the projection of the internal condyle

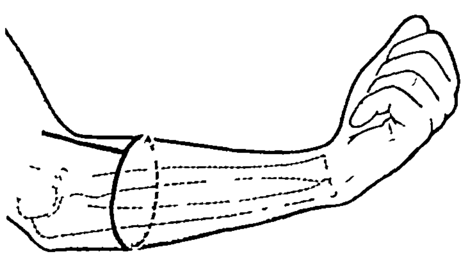

FIG 744

Kocher's incision for disarticulation of the elbow-joint

AMPUTATION THROUGH THE FOREARM

All are agreed that the lower the amputation the better the function A 3-in stump below the elbow-joint is the minimum length of functional value

From the instrument-maker's point of view the site of election for the division of bones is from 6 to 7 in below the olecranon Even if pronation and supination cannot be transmitted to the artificial limb, it is well that this movement should be retained Retention is only possible if the amputation is performed below the insertion of the pronator radii teres muscle into the middle of the outer surface of the radius

Position—The arm is held in full extension and pronated or supinated as required

Operation—Short modified circular skin flaps are made either on the dorsal and ventral aspects or laterally Alternatively an elliptical incision (Fig 745) may be used An elliptical incision is essentially a circular incision, but placed obliquely so that the

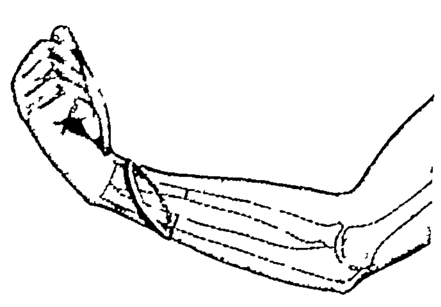

FIG 745

Elliptical incision for amputation through the forearm

upper portion is at the level of bone division the lower at a distance from the upper equal to the anteroposterior diameter of the limb After division of the muscles in circular fashion (Fig 740) the point of the knife is entered between the two bones to divide the interosseous membrane

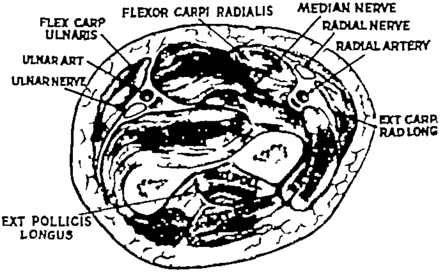

FIG. 740
Transverse section through the forearm.

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The majority of surgeons have either not met with an injury in which this amputation was indicated or condemned it. On the rare occasions that no portion of the hand can be saved, and there is sufficient skin to provide a flap or flaps, the operation should be seriously considered. The writer has never performed the operation, but he has seen several satisfactory results.

The tendons are divided by circular division a little below the level of the joint line. The wrist joint must be carefully located and opened from the radial aspect, otherwise the knife may be entered in error between the first and second rows of the carpal bones.

THE PRESERVATION OF THE HAND

Even in cases where all the fingers and thumb are hopelessly mutilated as much of the hand as possible should be preserved—The value of an amputation through, or proximal to the metacarpal bones at any level far exceeds that through the wrist joint or forearm A movable stump distal to the wrist joint is a great functional asset (Fig 748)

To conserve portions of fingers and above all as much as possible of the thumb should need no emphasis. There is a vast field for reconstructive surgery of the fingers and thumb To this end skin grafting tendon

Fig 747
Even the shortest stump of the thumb is of great utility
(*After Couch*)

transplantation and bone grafting have all been invoked successfully The transposition of a finger from the other hand to replace a lost thumb has also proved successful (Joyce) A single finger with good mobility is far superior to the most elaborate prosthesis A hand deprived of the thumb loses more than two-thirds of its functional value Even a short stump is a great asset to its owner (Fig 747) A stiff thumb with all the tendons destroyed and all the joints ankylosed, if placed in correct position for apposition of the fingers, adds very considerably to the utility of the hand

Fig 748
Recent photographs of a case operated upon in 1911 Four fingers, their metacarpal bones, the trapezius and the trapezoid were removed The first metacarpal now articulates with the scaphoid The patient is seen holding a razor

AMPUTATION OF FINGERS

The fingers and thumb are the most important part of the upper limb

When a surgeon is confronted with wounds of the fingers, and especially of the thumb, his thoughts should turn first to wound excision or débridement (as the case may be), the local application of sulphonamide, and immobilization with undisturbed dressings rather than to amputations On the other hand, primary disarticulation of a finger may obviate the possibility of spreading infection with little loss of function Often, disarticulation is to be preferred to a short stump of a finger (Fig 749)

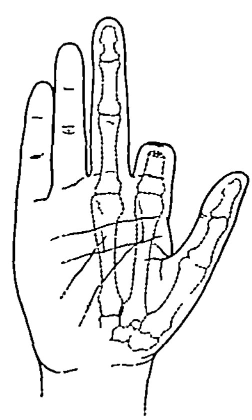

Fig 749
A poor amputation, the short index stump
(*After Couch*)

Surface anatomy—The three knuckles formed on the dorsal aspect of a finger when the joints are flexed lie proximal to the joint The three grooves on the palmar aspect have *the following relationship to* the joints The metacarpo phalangeal joint lies $\frac{5}{8}$ in above the

corresponding furrow the middle joint lies opposite the furrow and the terminal joint lies ¼ in. distal to the furrow

Amputation of the index or little finger—For total removal of either of these digits the best incision is a racquet incision but the racquet should be planned in such a way that a large lateral flap is formed The lateral flap in the case of the index finger is on the outer side and on the inner side in the case of the little finger For amputation of the index finger the incision is shown in Fig 750 A large external flap extending for almost an inch distal to the metacarpo phalangeal joint is fashioned. The racquet is completed by encircling the base of the finger with an incision passing through the interdigital cleft The disarticulation is then completed Some surgeons recommend the removal of the head of the metacarpal bone as a routine believing that the function of the hand is not

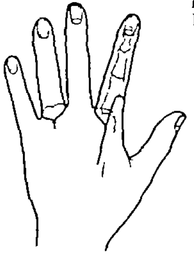

Fig 750

Suitable incisions for disarticulation through the metacarpo-phalangeal joint. In the case of the index and little fingers the flaps shown are employed. For the middle two fingers a racquet incision is recommended.

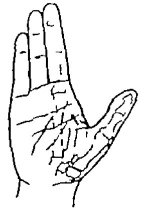

Fig. 751

A good amputation for the index finger Note the head of the second metacarpal has been removed obliquely

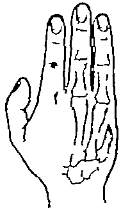

Fig. 752

A good amputation for the little finger. Note the metacarpal bone bevelled obliquely

impaired and that the cosmetic effect is very much better (Figs 751 and 752) Discretion must be used in this matter If the head of the bone is removed it should be divided obliquely as shown in Figs 751 and 752 The blood vessels are secured. Nerves in the case of a finger should be located if possible pulled down and divided at a high level. If the skin flaps are too long they should be trimmed before suture

Amputation of the middle or ring finger—A simple racquet incision is employed The handle of the racquet commences over the distal third of the dorsal surface of the metacarpal bone and is continued until it reaches the level of the middle of the web of the finger It is then carried downwards and forwards round the finger on each side and through the crease on the palmar aspect The incisions are made deeply to the bone The tendons are rendered tense and divided. The joint is opened by hyperextending the finger and incising the capsule from the palmar aspect The lateral

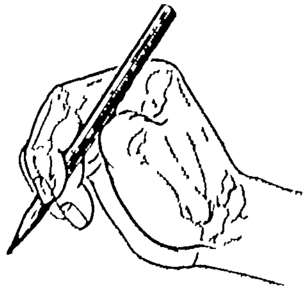

Fig. 747
Even the shortest stump of the thumb is of great utility.
(*After Couch*)

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Recent photographs of a case operated upon in 1911. Four fingers, their metacarpal bones, the trapezius and the trapezoid were removed The first metacarpal now articulates with the scaphoid The patient is seen holding a razor

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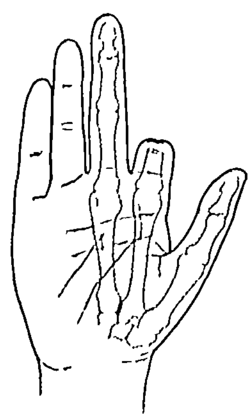

Fig 749
A poor amputation, the short index stump
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Surface anatomy The three knuckles formed on the dorsal aspect of a finger when the joints are flexed lie proximal to the joint The three grooves on the palmar aspect have the following relationship to the joints The metacarpo phalangeal joint lies $\frac{5}{8}$ in above the

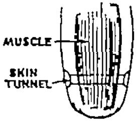


FIG 754
The principle of the Sauerbruch muscle tunnel motor

of a pedicle skin tunnel The tunnel of skin is passed through the belly of a particular muscle and out through an opening in the skin on the opposite side where it is sutured (Fig 754) When healing has occurred a metal rod is placed in the tunnel and by this means voluntary movement is imparted to an appliance

Reporting upon 403 patients upon whom Sauerbruch's[1] kineplastic amputation had been performed Horn found that 10 per cent of them had to have further surgical treatment chiefly on account of neuromata or furunculosis in the tunnels Also frequent repairs were necessary to certain parts of the appliance In spite of these discouragements approximately 60 per cent of the patients were well satisfied with their artificial limbs and were using the appliances daily without interruption or inconvenience

FIG 755
The principle of the pseudo-arthrosis motor

The pseudo-arthrosis motor was developed by Putti The principle is the separation of a terminal portion of bone to which opposing muscles are attached thus rendering the new formed terminal segment capable of voluntary movement (Fig 755) Besides flexor and extensor motors trimotors and quadmotors have been devised and an amputation of the forearm has been utilized to open and close an artificial hand

"Forcepization" of the radius and ulna is another principle of kinematization which differs from the others in that no appliance is required A K Henry made a forearm prehensile after a patient had lost his hand Fig 756 shows the amount of radius and ulna removed and the portion of radius which was detached to form a digit Tendons were made to operate this artificial digit The result was most encouraging (Fig 757) The patient learned to grasp a pencil and write with his animated forceps

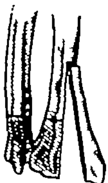


FIG 756
Henry's method of "forcepization."

FIG 757
Result in A. K. Henry's case of making the fore arm prehensile after the patient had lost his hand.
(*British Journal of Surgery*)

[1] F J Henry of Dublin informs me that when he visited the Sauerbruch clinic in 1923 he examined a number of patients upon whom the muscle tunnel motor procedure had been performed, and he was most impressed by the efficacy of the operation.

ligaments offer some resistance, but are easily severed Hamilton Bailey recommends Sherwood's amputation In this operation an attempt is made to reconstruct the interdigital cleft, and the racquet incisions meet on the palmar aspect in the form of a V, the apex of which points towards the wrist The V incision on the palmar aspect prevents the bulging pad which is so much in evidence after the orthodox removal of a finger By amputation distal to the metacarpal joint the function and cosmetic result is better

Amputation through the second joint—As already mentioned, the joint lies exactly opposite the furrow on the palmar aspect of the finger in flexion, and very slightly distal to the knuckle on the dorsal aspect A racquet incision or a long palmar flap are recommended for this disarticulation The divided extensor and flexor tendons are stitched together over the head of the first phalanx before the skin flaps are sutured By this means full movement of the stump is maintained (Fig 753)

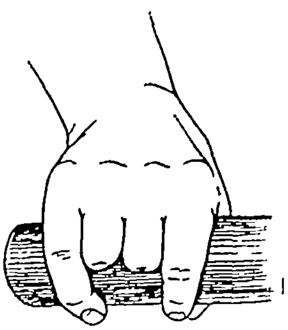


Fig 753

A good amputation The middle stumps increase the grasp and prevent approximation of the remaining digits (*After Couch*)

Amputation of a terminal phalanx—In practice it is found that injuries necessitate the formation of flaps from wherever they can be obtained It is often necessary to remove the head of the phalanx with bone forceps

Whenever possible the insertions of the flexor and extensor tendons should be left intact If this cannot be done they should be united over bone end, or at least anchored to their sheaths When the tip of the finger is amputated with a portion of the phalanx, the insertions of the flexor profundus digitorum and the extensor communis digitorum remain intact

If, instead of amputating through the proximal phalangeal joint, a portion of the middle phalanx can be preserved, the insertion of the flexor sublimis digitorum and a slip of the extensor communis digitorum will be spared at their attachment to the proximal end of the bone

KINEPLASTIC AMPUTATIONS

In order to impart more usefulness to a stump, particularly one of the upper limb, where a prosthesis is little more than an ornament, kineplastic amputations were devised The idea was originated by an Italian practitioner (Vanghetti) who experimented upon birds Seci, of Pisa, at the commencement of this century was the first to perform a kineplastic amputation In spite of a successful outcome the idea gained but little serious recognition, and very few attempts were made to repeat or develop this surgical innovation until, as a result of the 1914-18 war, a plethora of obvious material was available Even then large-scale attention was given to the subject only by Italian and German surgeons, and particularly the names of Putti in Italy and Sauerbruch in Germany have become associated with these ingenious procedures

The muscle tunnel motor is the particular form of kineplastic amputation which was developed at the Sauerbruch clinic The principle is the formation

Fitzmaurice Kelly had a large experience of secondary amputation through the hip-joint at the Brighton Pavilion at the close of the 1914 18 war He strongly recommended and practised performing this amputation by means of a posterior flap (Fig 760) equal in length to the anteroposterior diameter of the upper limit of the thigh

Disarticulation of the hip joint should only be attempted if there is no alternative

AMPUTATION THROUGH THE THIGH IN THE PRESENCE OF A FRACTURED FEMUR (ALL LEVELS)

The sleeve amputation was designed by the writer to meet certain emergencies with the least possible surgical risk and with a view to the conservation of the longest possible stump Two cases will be described briefly

Case 1—A strong labouring man was run over by a motor lorry and sustained a fracture about the middle of the shaft of the right femur He was seen ten days after the injury The leg from the foot to just below the knee was gangrenous the thigh was enormously swollen and had all the appearance of the early stages of moist gangrene which had already destroyed the leg The œdema vesication and discoloration extended upwards on the abdomen A tourniquet could not be employed owing to the condition of the soft tissues and for the same reason digital compression of the vessels was impossible An incision was made exposing the upper portion of the femoral artery for a length of 2 or 3 in in order to ascertain its condition The artery was pulsating in the upper portion of its course it was held by an assistant between finger and thumb A circular amputation was quickly performed *through the knee joint* just above the line of definite gangrene The incision was carried above the margin of the patella in front and the quadriceps extensor tendon divided the joint was opened in front and amputation completed by transverse division of the tissues behind The attachments of the soft tissues to the femur were separated (Fig 761) with knife and Jones gouge until the lower segment could be withdrawn from the line of fracture like a cork from a bottle by the rotary movements of a heavy bone forceps When the assistant released the femoral artery there *was no bleeding whatever at the end of the stump At this level the vessels were thrombosed and obliterated* The lower half of the thigh had now the appearance of a sleeve of a coat from which the hand and part of the forearm had been removed The sleeve was left open and packed lightly with gauze

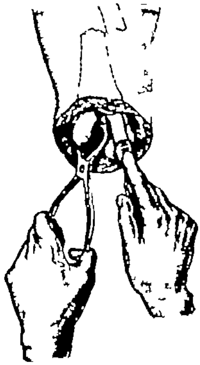


FIG 761

Wheeler's sleeve amputation. The limb is removed by circular amputation and the bone shelled out in the manner shown The wound is left open.

The man made an uninterrupted recovery except that there was an extensive sloughing of the skin in the upper portion of the thigh This

THE LOWER LIMB

AMPUTATIONS THROUGH THE HIP-JOINT

Primary amputation at the hip-joint following injuries of war carries so high a mortality that the operation seldom can be justified In the exceptional case there may be no choice The operation is planned so that the stump consists of the pelvis covered by skin and subcutaneous tissue An artificial appliance (tilting table) cannot be fitted to a flabby mass of muscle It is an advantage to leave the head and portion of the femoral neck *in situ* By adopting this plan, sinking in of the soft tissues is avoided, and the convex stump desired by the limb-makers is provided Amputations at a slightly lower level with retention of the lesser and greater trochanters usually result in a flexed stump, but to this projection a socket can be fitted without much difficulty

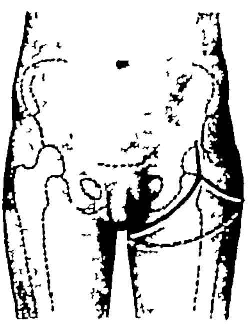


Fig 758

Incision for amputation through the hip-joint

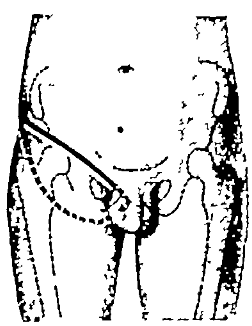
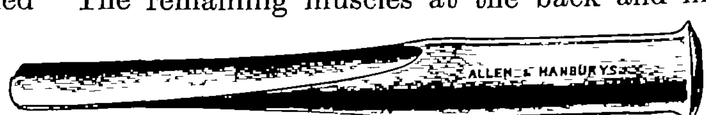


Fig 759

Fitzmaurice-Kelly's incision for amputation through the hip joint

Position—The buttock rests on the edge of the table, both limbs projecting over the latter The sound limb is flexed and secured to the leaf of the table, or held in abduction out of the way

Operation—A vertical incision 3 to 4 in in length is carried downwards from Poupart's ligament in the line of the femoral vessels These vessels are exposed and ligated as high as possible The incision is then carried obliquely round the inner side of the thigh about 4 in below the perineum It is then carried outwards to a point below the base of the great trochanter (Fig 758) From this point it passes across the back of the thigh to join the original incision Skin and fascia are raised up in the whole circumference The muscles on the outer side of the thigh are divided to the bone and the external circumflex artery ligatured With the limb elevated the attachments of the gluteus maximus and all the muscles attached to the great trochanter are divided The remaining muscles at the back and in the adductor region are similarly divided and the internal circumflex artery when seen is ligatured The shaft of the femur is cleared of muscle and periosteum with a Jones' gouge (Fig 760) This separation will be found most difficult along the linea aspera The joint is opened in front and the head of the femur dislocated from the acetabulum The ligamentum teres and remnants of the capsule will require division Whenever it is possible it is better not to dislocate the joint but to divide the femur through the neck or at a lower level, for reasons previously stated

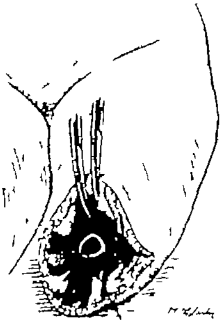


SCALE ½

Fig 760

Sir Robert Jones' gouge is more effective than the ordinary periosteal elevator

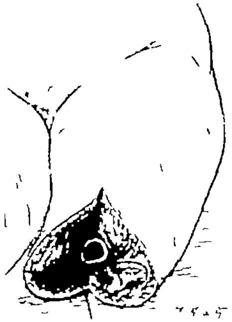
four or five days secondary suture or drawing the flaps together with adhesive plaster is usually followed by a satisfactory stump W R D Mitchell in a personal communication writes that he has seen a number of *below the knee amputations* with equilateral flaps apparently at least some of these had been performed because the principle of equilateral flaps was advocated



Pocketing

Fig 63

Drainage is imperfect when antero-posterior flaps are used.



Free Drainage

Fig 64

Equilateral flaps afford the wound perfect drainage

in the first edition of this work. Actually as the illustration shows it was for the thigh that the operation was and is recommended and then only in infected cases As Mitchell states if equilateral flaps are used at the modern seat of election below the knee with the idea of obtaining a permanent stump at this level many secondary above-the-knee amputations will become necessary

AMPUTATION THROUGH THE THIGH (Middle or Upper Third)

The seat of election for amputation through the *thigh* is usually stated to be about 4 to 6 in above the knee joint As a matter of fact 3 or 4 in above the knee is a better level for the division of bone

Above the seat of election every inch of bone should be preserved Five inches of shaft is the minimum capable of transmitting function to the artificial limb The value of the sleeve amputation in bad risk cases of infected fractures at a high level has been emphasized

Position—The same as in amputation at the hip joint

Choice of flaps—When operating through healthy undamaged tissues an elliptical incision (Fig 765) is the method of choice

area was skin-grafted Seven years after the operation he was seen by the writer, he was walking about with an artificial leg free from pain or discomfort

Case 2 illustrates the good result which can be obtained by amputating by the "sleeve" method well below and not above the area of infection A policeman was shot in the upper portion of the left thigh and sustained a compound fracture of the femur He was seen six months later There was no union of the fractured bone The upper part of the thigh was riddled with sinuses and each discharging sinus led to bare bone The patient was ill, pale, wasted and anæmic There was albumen in the urine

To obtain healthy flaps and remove the disease, an amputation through the hip-joint or through the neck of the femur was indicated, but the risk of such a procedure in such a case was realized

An amputation by the "sleeve" method was performed In this instance primary amputation through the knee-joint, as practised in the first case, was dispensed with The soft tissues were divided in circular fashion well above the level of the knee and the limb "extracted" A tourniquet was employed and the vessels and nerves dealt with in orthodox fashion The stump consisted of a long sleeve, riddled with sinuses in the upper portion The general condition of the patient improved rapidly, and after prolonged convalescence a painless serviceable stump remained, which lent itself well to the fitting of a modern artificial limb (Fig 762)

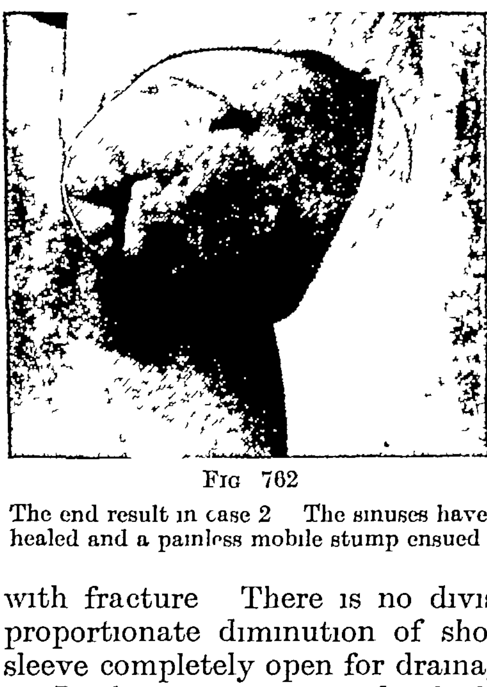


FIG 762

The end result in case 2 The sinuses have healed and a painless mobile stump ensued

The "sleeve" operation is suited particularly to bad surgical risk cases with fracture There is no division of bone with the saw and there is a proportionate diminution of shock It is usually advisable to leave the sleeve completely open for drainage and contraction

In the cases mentioned, which are but two of a series, the operation was completed in fifteen minutes

It must be left to the judgment of the operator whether to expose and ligature the external iliac artery or femoral vessels or to deal with the blood vessels during the circular division of the tissues lower down Much will depend on the condition of the soft parts immediately above and below Poupart's ligament

AMPUTATION THROUGH THE THIGH · SEPSIS FEARED (ALL LEVELS)

When judgment dictates that the wound must be left unsutured, equilateral flaps are recommended, the reason for which is apparent by reference to Figs 763 and 764 Should the fear of wound infection be unfounded, after

and behind at the level of bone section The ellipse crosses the thigh in front about 6 to 8 in lower down It is well to mark these two points by a small transverse cut in the skin before commencing operation

The incision is made through skin and fascia between the two points already mentioned The skin is raised on the front of the thigh in the form of a flap for about 3 in The knife is now carried through muscles in a sloping manner until the point at which it is intended to divide the bone is reached In this way the flap contains more and more muscle The skin on the back of the thigh is then raised and the muscles divided transversely to the bone (Fig 766) When the bone has been bared as high as is necessary a metal retractor (see Fig 738) is applied and while an assistant holds the leg steady in a horizontal position the bone is divided with Butcher s saw The vessels are doubly ligatured The sciatic nerve is pulled down gently injected with a local anæsthetic and crushed and ligatured The long saphenous nerve should be dealt with in a similar manner The tourniquet is now loosened and all bleeding controlled. It is usual in low amputations to control excessive contraction of the muscles by drawing them together over the bone with mattress sutures Muscle retraction does not occur in high amputations of the thigh

AMPUTATION THROUGH THE THIGH (Lower Third)

The amputation of choice is by an anterior flap with division of the femur 2¼ in above the level of the knee joint (J D Buxton) A large U-shaped flap (Fig 767) is marked out on the anterior surface of the limb extending when necessary down over the patella The length of the flap should be a little less than the anteroposterior diameter of the limb at the point of bone section (Skin stretches easily in this situation) The flap is raised to expose the quadriceps tendon which is divided and reflected upwards from the bone A transverse incision through skin and fascia is made across the popliteal space and joins the two extremities of the anterior incision The skin is raised slightly and all the muscles divided transversely to the bone The main vessels are dealt with in the usual manner The internal saphenous vein is ligatured It is necessary to identify the two popliteal and the long saphenous nerves The muscles are sutured together over the bone taking care that the bone is in the centre of the muscular tissue The scar lies posteriorly

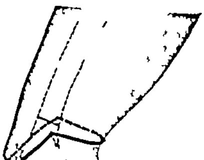


FIG. 767

The large U-shaped flap for amputation through the lower third of the thigh.

Tourniquet—In all cases the elastic tourniquet must be placed well above the level where it is intended to divide the bone, otherwise

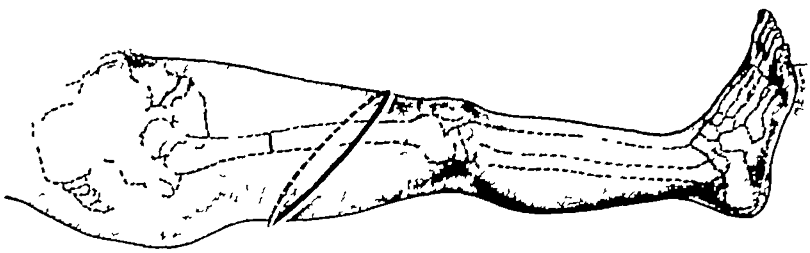


Fig 765
An elliptical incision for amputation through the upper third of the thigh

the tourniquet may slip In the case of a high amputation of the thigh, to prevent slipping two strips of bandage can be passed beneath

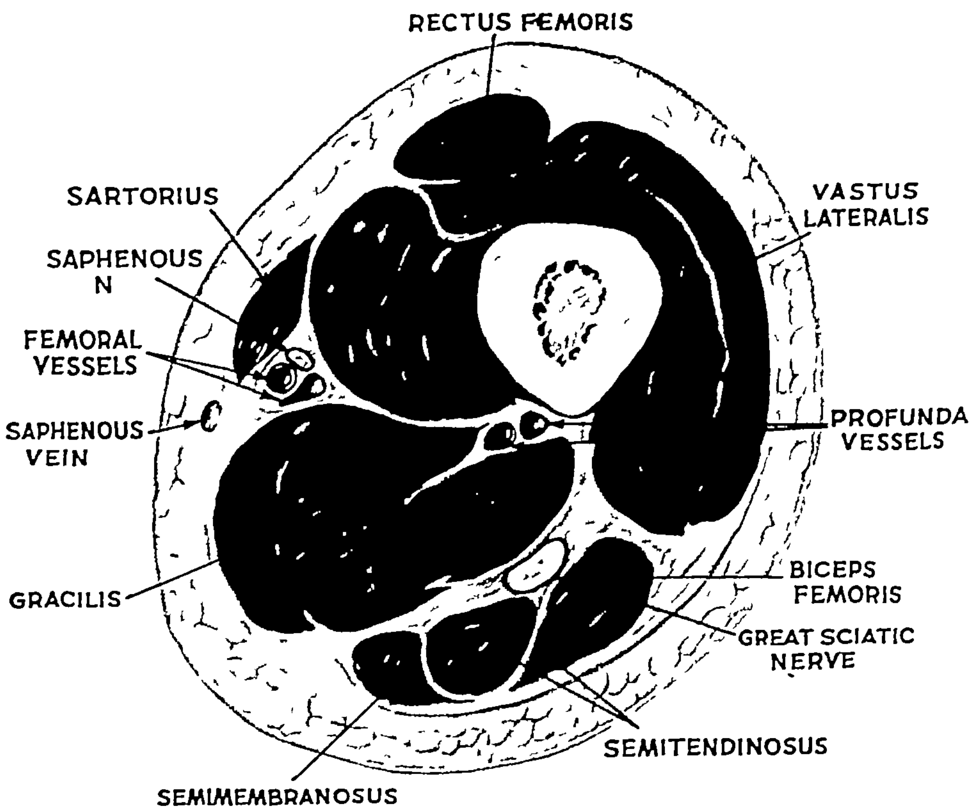


Fig 766
Transverse section through the middle of the thigh

the tourniquet An assistant exerts traction on these bandages towards the patient's head

Operation—An elliptical incision is made with its highest point above

is more desirable A very short below the-knee stump invariably becomes flexed and it is only possible to provide a peg leg

Position—The leg projects well over the end of the table By spanning the limb with finger and thumb the antero posterior diameter at the level of the future sawline can be gauged

Flaps must be taken from wherever the injury permits either a large anterior (Fig 771) or external flap is to be preferred The flap equals in length the diameter of the limb at the point of bone section The flap is raised and a circular incision connects its extremities Muscles are severed by circular division (Fig 772) just below the scratch on the skin The bones are laid bare with Jones gouge Didier s retractor is applied The fibula is divided at a higher level than the tibia with a strong rib shears or Butcher s saw The problem of how to deal with the fibula

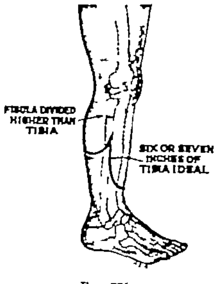


Fig 771
Amputation at the seat of election below the knee

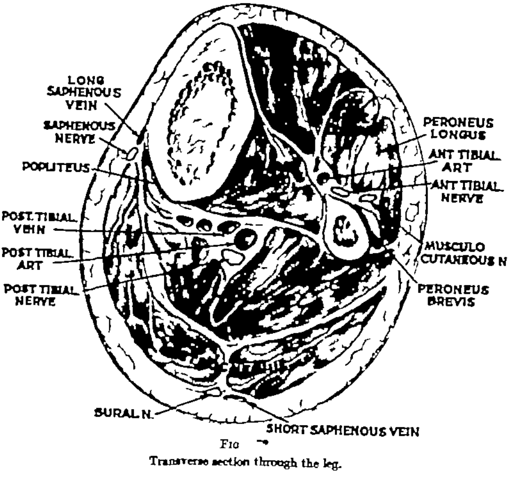


Fig 772
Transverse section through the leg.

AMPUTATION THROUGH THE LOWER THIRD UNDER LOCAL ANÆSTHESIA

When circumstances demand that the patient's vital resources must be conserved, A K Henry suggests that amputations of the thigh should be performed under local anæsthesia with the patient lying on the sound side (Fig 768) After the area of the proposed flaps has been infiltrated

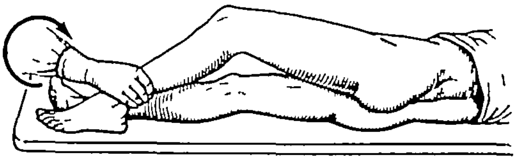


Fig 768

Showing the position of the patient A nurse holds the leg and rotates it as necessary without lifting the limb

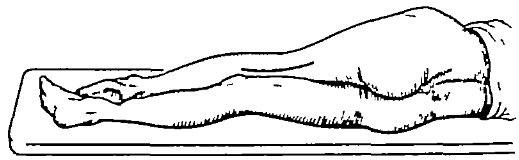


Fig 769

The knee falling across its sound fellow gives access to the back of the thigh The incision shown exposes the sciatic nerve for injection, and the main vessels for ligature

with local anæsthetic, the sciatic nerve is exposed and infiltrated likewise, at the same time the vessels are ligated For this purpose the primary incision extends from a hand's-breadth below the knee to a point three finger-breadths proximal to the line of bone section (Fig 769) The two heads of the gastrocnemius muscle are separated with the finger The finger then works proximally through the popliteal space and separates the slight adhesions of the mesial and lateral hamstrings

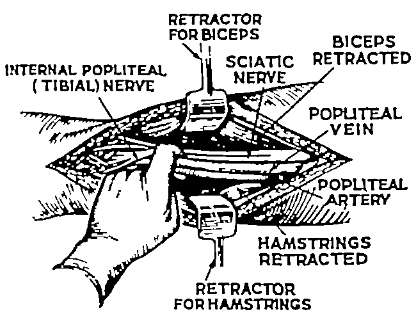


Fig 770

The popliteal vessels are hooked by the finger and traced upwards to be tied proximal to the adductor opening (*After A K Henry*)

The two main vessels lie anterior to the sciatic nerve, *i e*, nearer to the bone By tracing the vessels from below, they can be hooked off the femur with a finger (Fig 770) and can be easily tied above the level of the bone section Skin incisions are made from the mesial cut and flaps are made and muscles severed Ten minutes' time should elapse between injecting and cutting the sciatic nerve It is important after removing the limb not to pull out the proximal end of the nerve and cut it short at a point unprotected by anæsthesia The saphenous nerve must also be injected before it is divided

AMPUTATION THROUGH THE KNEE-JOINT

There are very few indications for amputation through the knee-joint The operation has been abandoned in large measure in favour of amputation through the lower third of the thigh

AMPUTATIONS BELOW THE KNEE

By common consent the seat of election for amputation of the leg is 6 or 7 in below the lower border of the patella with the leg flexed The point for bone section should be marked by a scratch on the skin If less than 4 in of the tibia can be saved, an amputation above the knee-joint

ankle joint The modern amputation leaves about 2 in between the end of the stump and the ground The operation should not be performed in the presence of gross sepsis and it will not be successful if there is much injury to the integuments in the neighbourhood of the heel Syme s amputation is undoubtedly the best operation in the lower limb Elmslie supported this view He said it is objected to by some limb makers because it is more difficult to fit than is a straightforward amputation through the middle of the leg but this is much more than counterbalanced by the facts that a patient with a good Syme amputation can walk ten to fifteen miles run jump and play such games as tennis and golf almost without his disability being noticed

In many of the cases which failed in the last war the operation was either contraindicated or performed under adverse conditions Furthermore a proportion would have been a permanent success if provided with a good fitting prosthesis or if the modern incision had been employed

Position—The foot projects over the end of the table An assistant facing the operator holds the leg with both hands above the ankle joint He raises and lowers the limb at the different stages of the operation

Operation—The modern Syme s amputation is by the elliptical incision The lower portion of the ellipse traverses the foot 1 in in front of the heel (Fig 776) The anterior portion is carried across the front of the ankle The incision commences behind the tip of the internal malleolus It crosses the sole to a point ½ in above the tip of the external malleolus All structures are divided to the bone The extremities of this incision are connected by an incision across the front of the ankle-joint with a slight inclination upwards All the structures are divided to the bone and the ankle-joint is opened

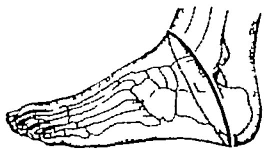


Fig 776
Incision for the modified Syme s amputation

After division of the lateral ligaments the astragalus is dislocated forwards by depressing the foot With the foot still more plantar flexed the back of the os calcis is cleared of tendo Achillis and heel flap This is a procedure of some difficulty the knife must be kept in close contact with the bone Great care is necessary not to buttonhole the skin when the prominence of the os calcis is reached When working on the inner aspect the posterior tibial artery must not be injured or the vitality of the flap is endangered.[1] The secret of success in dealing with the heel flap is to keep close to the bone Jones gouge here as elsewhere is of considerable assistance When the foot is removed the tibia and fibula are cleared and divided with a saw about ½ in above the joint level (Fig 777) The anterior tibial vessels and the internal saphenous vein are sought and ligatured. The anterior tibial and musculo-cutaneous nerves should be dealt with in the orthodox manner When the plantar vessels have been secured the large posterior tibial nerve is divided above the level of bone

[1] The vitality of the heel flap depends upon (a) the termination of the peroneal artery on the lateral aspect and (b) large branch of the tibial artery on the medial aspect These vessels anastomose freely in the tissue which should constitute the flap and the vitality is seriously imperilled unless the knife is kept strictly to the bone

requires attention. Some surgeons believe that the retention of the head assists in keeping the stump in the socket. The majority take the opposite view. They claim that complete removal of the fibula provides the following advantages: —

(a) Flaps, otherwise too small, will suffice.
(b) A prominence of bone which stands pressure badly and upon which the external popliteal nerve lies is eliminated.

It is necessary to make the anterior part of the tibia smooth by applying the saw about half an inch above the intended line of amputation and dividing the crest obliquely from above downwards and backwards until the level for the transverse division of the bone is reached. The saw is then removed and applied transversely (Fig. 773). In this way the sharp crest is bevelled.

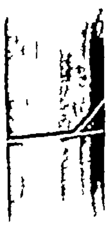


FIG. 773

Method of bevelling the crest of the tibia

Immediate after-treatment.—Many legs become flexed at the knee owing to faulty early treatment. Immediate plaster of Paris fixation of the stump including the knee avoids this troublesome complication. When the plaster is changed for removal of the stitches, full movements of the knee-joint should be encouraged. The second plaster is applied to the stump below the joint. If there is any tendency to flexion contracture, a back splint worn at night will be sufficient to maintain correction.

SYME'S AMPUTATION

Syme's amputation (1842) is not favoured by some recent writers. There is little doubt that with a proper selection of cases and correct technique lasting results accrue. I have been in touch with patients upon whom Syme's amputation was performed by my surgical seniors as long as fifty years ago. These patients, now in advanced years, have led an active life and were not handicapped in hunting or other sports (Figs. 774 and 775). This is the more remarkable seeing that the operations were undertaken at a time when asepsis was in its cradle. Humble individuals use the end-bearing stump in an elephant boot, with perfect satisfaction. They can walk without any artificial limb if they so desire. This is a considerable advantage over amputations at a higher level.

FIG. 774

Stump fifty years after Syme's amputation performed in 1891 by the writer's father

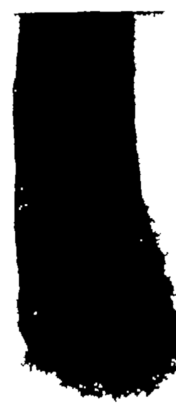


FIG. 775

Radiograph of the stump fifty years after amputation for a crushing injury when the patient was 34 years of age

The patient is now 84 years of age, he hunts, dances and shoots regularly. (*Photograph, 1941.*)

The classical incision has been modified and the bone divided at a higher level.[1] By adopting an elliptical incision a shorter heel flap is provided. By the higher division of bone, ample room is left for the artificial

[1] See also Appendix chapter.

Disarticulation of the terminal phalanx is accomplished by a long plantar flap similar to that formed for partial amputation of a finger In the case of the toe however the flap is dissected back and the joint opened on the plantar aspect A transverse dorsal incision divides the extensor tendon and completes the amputation

Amputation at the metatarso-phalangeal joint—The same flaps as in the case of fingers are excellent (see p 760) The head of the metatarsal bone of the great toe is large and an internal flap of suitable dimensions must be provided in order to cover it

THE CARE OF AMPUTATION STUMPS

The prevention of joint stiffness and contractures—The value of plaster of Paris as a first dressing to be followed after the stitches have been removed by a skin tight plaster has been emphasized

Early active movement of the adjacent joint should be encouraged—In most instances a certain amount of movement can be allowed after the third or fourth day In all cases, after the stitches have been removed regular exercising of the joint should be instituted A splint worn at night will aid in preventing contractures

Shrinkage of stumps—Many of the divided muscles cease to function they tend to shrink progressively Pressure on the stump from an artificial limb causes further shrinkage which is not complete for many months It is therefore most desirable to fit some form of prosthesis as soon as possible for not only will this hasten shrinkage of the stump but it has a good psychological effect upon the patient Moreover a patient who has learned to rely upon crutches does not accommodate himself readily to the use of an artificial limb

FIG. 780
The fibre cone pylon. (*G M Huggins*)

Temporary pylons—The common practice in this country is to supply a temporary prosthesis and to alter this from time to time to conform with changing measurements of the stump

THE FIBRE CONE (Fig 780) is light and cheap The bucket is well padded and can be easily altered to fit the decreasing diameter of the stump

THE PLASTER PEG LEG (Fig 781) is also in common use It can be constructed from a portion of a crutch sawn off at the correct level and plaster of Paris suitably padded

In America the limb makers prefer the fitting of the permanent limb at once The socket is altered from time to time to conform to the changing measurements of the stump It is argued that faulty habits of walking

division Some tendons may require to be shortened Lateral drainage is usually advisable (Fig 778) The drain may be removed in twenty-four hours and the stump enclosed in plaster of Paris

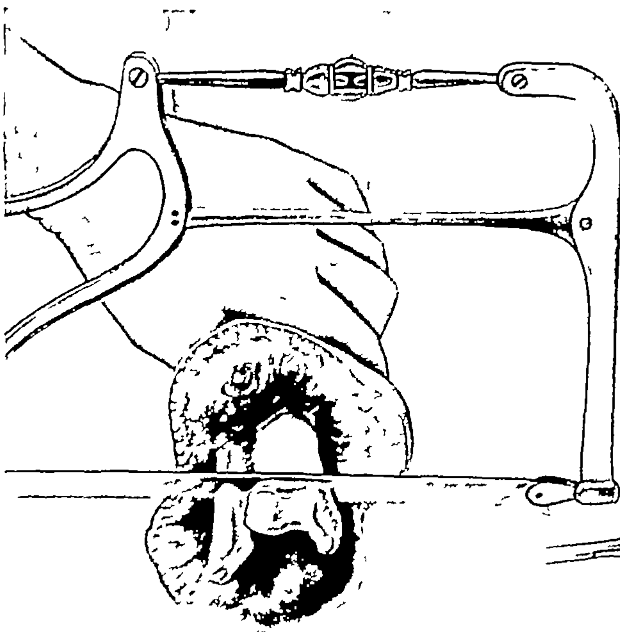


Fig 777
The bones are divided ¾ in above the joint level (*After P D Wilson*)

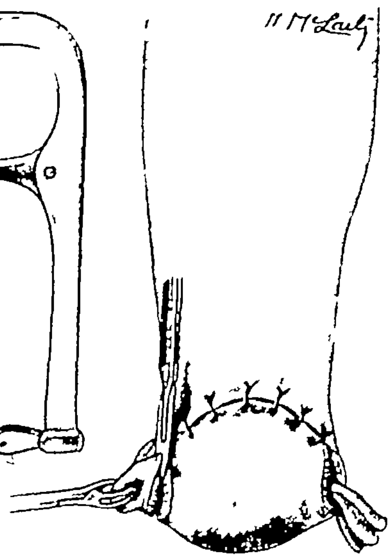


Fig 778
"Dog ears" are removed and dependent drainage afforded

AMPUTATION OF THE FOREPART OF THE FOOT

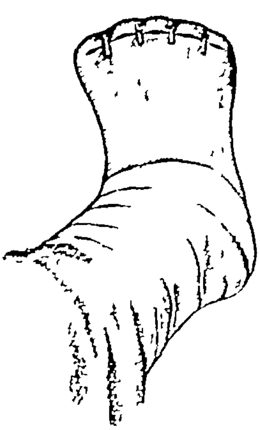


Fig 779
While amputation through the tarsal bones is unsatisfactory, amputation through the metatarsal bones gives a very useful foot, even if all the toes are lost

Amputations through the tarsal bones are not satisfactory When all the toes are injured past repair, the raising of dorsal and plantar flaps and removal of portions of the metatarsal bones is preferable to an amputation of a more radical kind (Fig 779) Sir Robert Jones practised this operation after removal of the astragalus in severe forms of claw foot He stated that the results were excellent No prosthesis is required, and the patient wears an ordinary shoe in which the toe portion has been blocked in

AMPUTATION OF TOES

Little disability arises from amputation of the four outer toes, but the heads of the metatarsal bones should be spared whenever possible S T Irwin of Belfast states that it is rare to find an amputation of the great toe which allows a soldier to belong to category "A" The head of the first metatarsal bone is such an important weight-bearing point that every effort should be made to spare it

fashion The patient is warned before again using the artificial appliance to wash the stump with methylated spirit and powder freely with talc twice a day X ray treatment is of value (Huggins)

Stump osteomyelitis is dealt with either by exposing the end of the bone through the old scar or making a new lateral incision An inch or more of the bone may be excised *in toto* or an abscess and sequestrum treated locally in the usual manner

Spurs—When these are painful they are removed Care is taken not to disturb the periosteum or surrounding bone more than is essential in order to avoid recurrence It may be necessary to remove a segment of bone including the entire circumference when the spurs are multiple

Bursitis sometimes occurs over the head of the fibula but is a rare complication Removal of the fibula with the bursa effects a cure

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develop from the use of a temporary limb, and that it is less expensive to alter or make a new socket than it is to construct and alter a temporary limb as a preliminary to the permanent fitting

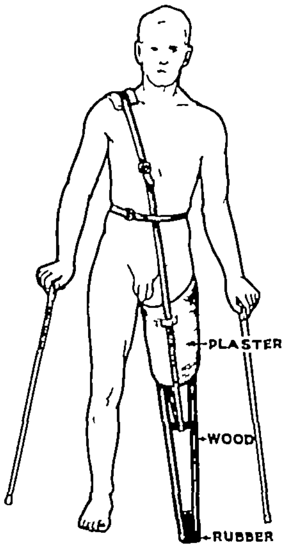

FIG 781
A plaster peg-leg

AFFECTIONS OF STUMPS

Painful stumps—The cause of pain may be obvious One of the commonest causes is a badly fitting prosthesis during the period when the stump is shrinking progressively On the other hand, severe and continued pain sometimes occurs without any obvious cause Such pain may be so continuous that the patients become addicted to morphia or occasionally may be driven to suicide If the pain is the result of terminal neuromata, injection of a local anæsthetic as a diagnostic measure gives complete, but usually only temporary, relief Resection of the neuromata is frequently unsuccessful It is better to divide the nerve at a higher level and join the divided ends again by accurate suture Sometimes the pain has its origin in the sympathetic nerves, in which case it is often accompanied by vasomotor and trophic changes Under these circumstances injection of a local anæsthetic usually fails to give relief, this is a signal aid to diagnosis In such cases periarterial sympathectomy may give striking relief, but often this relief is but transitory, and removal of the sympathetic ganglia above will be required Cases of extreme hyperæsthesia suffer as a rule from a true neuritis spreading upwards

Re-amputation for painful stumps should be reserved for those cases in which there is definite localized osteomyelitis at the end of the bone, or where the stump is definitely unsuitable for the fitting of an artificial limb

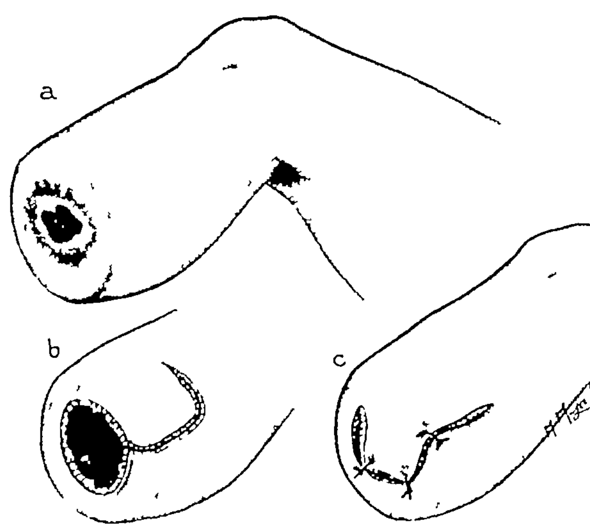

FIG 782
A plastic operation for a painful and adherent stump scar (*After P D Wilson*)

Painful and adherent scars should be excised, especially if situated at a pressure area of the artificial limb A wide excision should be performed, and in suturing, the new scar should fall, whenever possible, into a different position from the old (Fig 782) In troublesome cases a well-planned skin graft is successful

Eczema and ulcers of a troublesome nature can only be cured by discarding the limb for the time being and treating the condition in orthodox

Should the surgeon not feel quite certain as to whether he is justified in amputating as for the final fitting of an artificial limb he can compromise by stitching the flaps together loosely with drainage If all goes well the suturing can be completed in a few days

THE GUILLOTINE AMPUTATION

The guillotine amputation consists simply of a circular division of skin muscle and bone at the same level (Fig 783) the opening of fascial planes is reduced to a minimum Recently a large number of surgeons have con demned this amputation as obsolete Certainly I have encountered guillotine amputations which have been performed at unfortunate levels and which have received incorrect or inadequate after treatment Nevertheless I am convinced that the operation deserves a permanent place in war surgery I am therefore most anxious that the precise position should be made clear

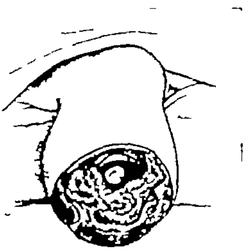

Fig 783

Guillotine operation made close to the site of a fracture in a case of gunshot wound followed by gas gangrene of the foot. (*Fitzmaurice-Kelly British Journal of Surgery.*)

Assuming that in a case of gross sepsis amputation is indicated at a level which will be suitable for an artificial limb the amputation should be carried out with equi *lateral or anteroposterior flaps* which can be left open and sub sequently sutured when the wound is granulating healthily Hamilton Bailey has correctly said that lateral flaps will give the best drainage but they leave a scar which is less good from a limb fitting point of view Each case must be decided on its merits A good working rule is that whenever possible a guillotine operation should be avoided at a good level for an arti ficial limb If the amputation *must* be performed at such a level except under extenuating circumstances skin flaps should be fashioned and the wound left open widely However there is another side to the question which can be well illustrated by two examples —

(a) Examination shows that it will be possible to conserve 7 in. only of femur measured from the top of the great trochanter The skin is so badly damaged that no further length of skin is available To remove more bone in order to make skin flaps would render the stump (in most cases) useless for the fitting of a prosthesis giving hip-control consequently if more bone is sacrificed, the patient might just as well lose the whole limb Here the guillotine amputation is the only rational alternative. Providing the after treatment to be described is adopted, this precious stump can be saved.

(b) The whole foot has been hopelessly mangled and is infected. In other words, the time for performing a permanent mid tibial amputation with safety has passed. Here a guillotine amputation through the lowest part of the leg is indicated, for the shaping of flaps is superfluous re-amputation will be required in any case.

There are still surgeons who think that a guillotine amputation will

CHAPTER LXIX

AMPUTATIONS FROM THE ARTIFICIAL LIMB POINT OF VIEW, WITH SPECIAL REFERENCE TO THE GUILLOTINE AMPUTATION

IT is hoped and believed that most of those who suffer amputation as a result of war injuries will eventually be fitted with an artificial limb, and the planning of the amputation with this object in view should be borne in mind, when possible, from the first Comparison of a work on Operative Surgery of 1912 with, say, the late Muirhead Little's book on Amputations and Artificial Limbs (1922) shows that great advances were made as the result of experience gained during the 1914-18 war Many amputations became permanently obsolete for treatment purposes and only remained as possible exercises in operative surgery on the cadaver

Twenty years' experience at Roehampton and elsewhere has proved that the dictum, "the surgeon amputates and the limb-fitter must do his best with the stump," is a fallacy On the contrary, close collaboration between surgeons and limb-fitters leads to the best possible results Time has proved the durability of these results in the face of increasing age and failing circulation These results were due to great improvement in the mechanism and lightness of artificial legs, it being recognized that a patient might easily walk ten miles on an artificial leg, whereas he could, perhaps, only limp a hundred yards on a bad foot For the leg, therefore, conservative surgery has lost its importance It has always been otherwise for the arm, as the possession of even one intact digit capable of opposition to a prosthesis is better than the best artificial arm that has yet been made

SELECTING CASES IN WHICH THE ARTIFICIAL LIMB SHOULD RECEIVE MAJOR CONSIDERATION

Obviously, if gas gangrene or gross sepsis is present, the only consideration is to save the patient's life, and an amputation which rids the patient of infected tissue and gives free drainage must be given prior consideration Whether or not it is suitable for a permanency is of little moment In the absence of signs of infection, due consideration should be given to preferable sites for amputation from the artificial limb point of view Investigations are proceeding regarding the time after injury during which (in the absence of signs of visible infection) it is permissible to perform amputation intended to be permanent At the time of writing it is considered that the surgeon who encounters a limb, obviously non-viable, within five to eight hours of the injury should be prepared to amputate as for the final fitting of an artificial limb, thus shortening the period of invalidism

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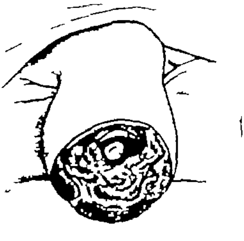

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Dakin's Oil

℞

Dichloramine-T	2 parts
Chlorinated eucalyptol (Martindale)	20 parts
Chlorinated paraffin (Martindale)	80 parts

RE-AMPUTATION

It will be seen that after the guillotine amputation re amputation is rarely necessary indeed after the separation of the terminal sequestrum and the covering of the wound with granulations if the above after treatment has been carried out approximation of skin edges without the sacrifice of more bone is the rule I have seen recently a certain number of cases where re-amputation has been performed prematurely leading to successive re-amputations from recurrent sepsis

Experience has taught us that before re-amputation can be considered certain conditions must obtain —

(*a*) There must be no œdema in the stump
(*b*) No part of the stump must be tender to pressure
(*c*) All sequestra must have separated and the wound be covered with healthy granulations.
(*d*) A radiograph of the stump reveals no signs of periostitis

At the time of re-amputation granulations should be swabbed with pure carbolic and sealed off by towels from the rest of the stump No instrument used in the re-amputation should come in contact with the wound

PERMANENT AMPUTATION FROM THE LIMB-FITTING POINT OF VIEW

The best stumps are thin and conical, provided that their nutrition is adequate and this is likely to be the case if they are not too long It was once thought that the longer the stump the better leverage was given to the control of the prosthesis but this is not the case with modern artificial limbs Where circulation is poor ulceration occurs from pressure and friction in the socket and experience has taught us what length of stump will be most likely to stand the test of advancing years

Flaps—The total length of the flaps should not exceed the diameter of the limb if they do so a pouchy end is liable to result The pouch tends to become filled with serum which is easily infected Moreover the excess tissue gives rise to a lax puckered covering From this arises a tendency to intertrigo from the contact of perspiring skin surfaces when confined in a socket It is therefore highly important that the scar should be unpuckered Accurate suturing of flaps of correct length to cover the stump and no more is essential Before the stitches are inserted a trial is made by approximating the skin edges by tissue forceps If the flaps are too long they are reduced in size All redundant tissue between the skin flaps and the bone should be removed This applies especially to fat as muscle will waste whereas fat will not No effort should be spared to produce a linear scar flush with the surface

If these points are neglected puckered scars will be sure to follow and so regularly do they give rise to trouble that it is advisable to excise them and resuture before an artificial limb is fitted

always require re-amputation On the contrary, frequently such amputations on the thigh, arm, forearm and, occasionally, leg have been fitted with a satisfactory prosthesis

Perhaps the most important consideration in the post-operative treatment is early and adequate skin traction The principle of post-operative traction was started at the Military Orthopædic Hospital, London, during the 1914-18 war, and twenty years' experience has taught us that if it is used correctly re-amputation is very rarely needed Naturally, if the amputation be but a temporary one, as in the case (*b*) cited above, no traction is necessary In a high femoral guillotine amputation, or even one in which equal flaps have been employed, it is as well to ligate the common femoral artery and vein in continuity just below Poupart's ligament, as secondary hæmorrhage is to be feared

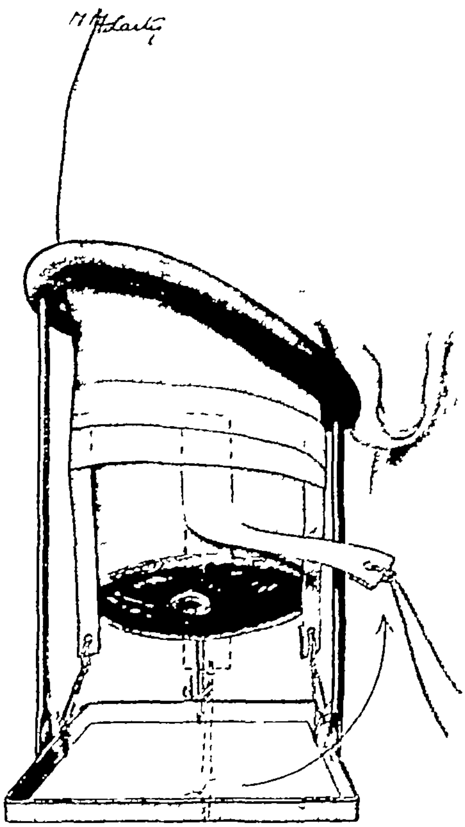

FIG 784

Apparatus for efficient skin traction of the guillotine amputation Traction should be applied twenty-four hours after the operation and continued until the wound has healed

After-treatment—When traction is indicated it should be begun twenty-four hours after the operation Four pieces of adhesive plaster are applied in the manner shown in Fig 784, the adhesion reaching as near to the edge of the wound as possible Two circular pieces are placed as shown, and tapes are fastened to the free ends of the four strips A truncated Thomas' splint is then applied and the tapes are tied thereto and kept taut Skin is elastic and by the constant traction it covers the granulating surface The separation of a ring-sequestrum from the exposed bone surface serves to hasten this end

Dressings—For the first two or three days a dressing soaked in flavine-paraffin is applied

Flavine-paraffin

℞

Acriflavine	gr viii
Spirit rectif	℥vi
Paraffin liq	℥xxxiv

Dressings should be as infrequent as possible When the flavine-paraffin is discontinued a simple dry dressing, consisting of a few layers of gauze, is recommended after spraying the wound with Dakin's oil Dakin's oil is anæsthetic and deodorant

a fixed hip Both from the point of view of fitting and from that of giving a feeling of confidence to the patient it is very important that the socket should fit well and that the patient should feel that the limb is part of himself and that it will not fall off Disarticulation of the hip joint leaves a stump which tends to fall in and leave no bony prominences to which

FIG 785

Disarticulation at the hip-joint. Note the lack of prominence of the lateral contour which makes the fitting of an artificial limb so difficult.

FIG 786

Pertrochanteric amputation. Showing the prominence of the lateral contour Upon this an artificial limb socket can be moulded.

FIG 787

Subtrochanteric amputation.

FIG 788

In a subtrochanteric amputation the ilio-psoas muscle flexes the stump and gives rise to an anterior prominence

the socket can be moulded (Fig 785)[1] Even if the head neck and great trochanter can be left there will remain a prominence (Fig 786) which is of great service From a limb-fitting point of view by far the best amputation is one just below the lesser trochanter (Fig 787) The short stump is flexed by the ilio-psoas into a sitting position and protrudes anteriorly giving a second prominence (Fig 788) Should it be found possible to

[1] Figs. 785 to 790 have been reproduced by the courtesy of Messrs J E. Hanger & Co. Ltd., of Roehampton House London, S.W 15

Treatment of nerves—For some time it has been recommended that nerves should be pulled down, crushed, tied and divided. Some surgeons even advised the injection of alcohol or carbolic. The object of this treatment was the prevention of terminal neuromata; actually, no treatment will prevent their formation. Nerves are very sensitive, and any crushing or injection will cause traumatic or alcoholic neuritis. The *final situation* of the cut nerve-end is also important from a limb-fitting point of view. When, eventually, the patient wears an artificial limb, the only part of the stump which is not subject to pressure from the socket is the end. Hence it is better that the sensitive nerve-ends should be at the end of the stump, as no pain is produced by pressure on the intact nerve trunk. Nerves, therefore, should *not* be shortened or in any way traumatized. There is one exception to this rule and that is the Syme amputation, where weight-bearing is expected and the ends of the nerves subjected to pressure.

SPECIAL AMPUTATIONS

Shoulder—Amputations through the shoulder-joint leave a stump where the acromion protrudes, and it is difficult to fit a prosthesis. Where possible it is better to amputate through the surgical or anatomical neck of the humerus, leaving a more sightly stump and one to which a limb can more easily be fitted.

Arm—The ideal length is 8 in. below the acromion. A stump measuring less than 5 in. from the acromion cannot be fitted with an artificial arm controllable by the patient's shoulder. If the stump be longer than 3 in. above the elbow-joint, a good artificial elbow cannot be made.

Forearm—The ideal length is 7 to 8 in. below the tip of the olecranon. Four inches is generally regarded as the minimum length worth preserving, but I have seen many cases with less than this who have useful function.

Wrist—Amputation through the wrist is a subject of controversy. The claim that this operation retains the power of pronation and supination in a prosthesis cannot be upheld. Simple examination of an artificial limb shows that this cannot be true. Either the movement takes place inside the socket, in which case the socket does not fit and the arm is useless, or the socket fits and the movement cannot take place. In many cases, especially in double amputations, patients have developed extraordinary skill in the use of their stumps, even without any prosthesis, but in time a stump of this length becomes ill-nourished. Obviously, if it is useful it should be retained, for it is always possible to re-amputate should the occasion arise.

Hand—Here conservative surgery must hold the field, as, provided there are acting tendons and movable joints, reconstructive surgery can do much, and even one good digit can be made to oppose to a prosthesis. Every part possible should be kept. Reconstructive operations can be considered at leisure.

The region of the hip-joint—Patients who have suffered an amputation in this region for reasons of disease, such as tuberculosis, will rarely wear a prosthesis, but the healthy wounded should hope to do so. The prosthesis will consist of what is known as a "tilting table." Here the pelvis is contained in the socket and the patient walks with a swing of the body and

a fixed hip Both from the point of view of fitting and from that of giving a feeling of confidence to the patient it is very important that the socket should fit well and that the patient should feel that the limb is part of himself and that it will not fall off Disarticulation of the hip joint leaves a stump which tends to fall in and leave no bony prominences to which

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amputate by a short anterior skin flap and a long posterior flap containing most of the gluteal muscles, the tuber-ischii will be well covered and the patient will be sitting in the socket on those tissues on which he is accustomed to sit

Thigh—An amputation leaving less than 5 in of femur, measured from the top of the great trochanter, can rarely be fitted with a prosthesis giving hip control, and it is better to amputate as above for a "tilting-table" if more cannot be preserved A thigh stump should never reach a lower point than 4 in above the adductor tubercle, as a longer stump interferes with the mechanism of an artificial knee

From 10 to 11 in measured from the great trochanter is the ideal length

The hamstrings should be cut rather short, as a strong young person can be fitted with a stump-controlled limb By this is meant that in walking the artificial limb is controlled by the stump, which is braced back Should the hamstrings be adherent to the terminal scar, pain may be caused thereby by their pull on the scar A bony spur will nearly always form on the postero-internal aspect of the femur, but is of no importance provided it does not impinge on the suture line This should be prevented, where possible, by the planning of the flaps Operations for the removal of bony spurs are useless

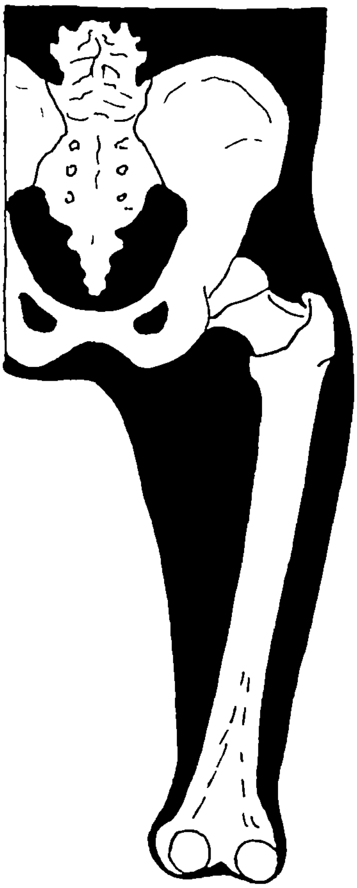

FIG 789

Amputation through the knee joint gives a bulky stump which is difficult to fit with a satisfactory prosthesis

Knee-joint—Amputation through the knee-joint is often justifiable as a temporary measure, and the stump can be fitted with a prosthesis The end of the stump is, however, awkwardly shaped (Fig 789) and the artificial knee-joint is necessarily bulky and clumsy Usually such cases will need re-amputation at a better level

Kneeling-stumps—There are three points in the lower limb on which weight can be borne—the tuber-ischii, the flexed knee and the heel The first is now employed in the majority of cases, even when the amputation is below the knee The last is used in the Syme's amputation

Certain conditions may, however, obtain where the first cannot be used—extensive scarring in the region, etc —and in such cases it may be imperative to revert to the principles of Nelson's day and fit the patient with a limb on which he kneels, a modern improvement on the old wooden leg

For this amputation a length of tibia of under 3 in is needed The scar must be placed well to the back and most of the gastrocnemius removed

Leg—For many years we advised that the ideal length of a below-knee amputation was 7 in measured from the top of the tibia Experience has shown us that with advancing years the ends of such stumps become ill-nourished, and we now advise a length of 5½ in Such

stumps can be fitted as easily as the longer ones and are more durable. It is very important that the fibula be cut 1 in shorter than the tibia for two reasons —

(a) To prevent cross union which always gives a painful stump as it interferes with the spring action afforded by the free shaft of the fibula

(b) To make the stump more conical (Fig 790)

Fig 790

Amputation below the knee The ideal stump measures 5½ in., and not in. as taught formerly Note that the fibula is shorter than the tibia by 1 in.

The head of the fibula should always be retained, as the bony prominence enables the moulding of the socket to assist in the retention of the limb exactly as has been explained above for the hip region

Syme's amputation—Much controversy has arisen in the last twenty years about this operation It is no longer performed as Syme originally planned it but the idea is the same It is designed to be weight bearing Originally patients who had had this operation were fitted with an elephant-boot a circular leather sole attached to the stump by a leather bag and the results were very satisfactory I have done this operation on natives in the Pacific islands who had lost a foot from shark bite and have seen them getting about afterwards on their uncovered stump quite satisfactorily For civilized man however it is not satisfactory It needs a prosthesis of great clumsiness and the necessary encirclement of the leg in a leather socket which is hot heavy and unventilated increases the natural tendency to malnutrition in a stump of this length

The result is that the heel flap becomes displaced backwards there is periostitis of the bone ends circulation becomes poor and callosities form Statistics published by the Ministry of Pensions based on cases from the last war show that the average period during which such cases were able to employ full end bearing (the essential of the operation) was seven and a half years From a limb fitting point of view the Syme amputation cannot be compared with a good mid tibial amputation

Tarsus—All amputations through the tarsus Chopart Lisfranc etc have in the majority of instances proved unsatisfactory

AFTER-TREATMENT OF STUMPS

In the upper limb little or none will be needed The patient should be encouraged to maintain all movements of his joints from the first

In the lower limb it is important that as soon as the wound has healed

every effort should be made to render the stump suitable for limb-fitting as soon as possible Stumps will shrink from atrophy of muscle, and it would be uneconomical to be forced to make a succession of sockets of diminishing size As soon, therefore, as the wound is soundly healed, the stump should be bandaged with an elastic bandage from the distal end This will cause shrinking of the tissues until a permanent state is obtained The patient should never be allowed about on crutches with his stump dependent unless it be bandaged

Massage has no part in attaining the desired result, as instead it only serves to irritate nerves, but active movements should be encouraged

CONTRACTURES

In fitting thigh stumps, one of the greatest difficulties is flexion-contracture of the hip This is avoidable and is often due to the habit of supporting a recent thigh amputation stump on a pillow On the contrary, the stump should be held extended by a towel held by sandbags It must be remembered that, if the patient is in a sitting position in bed, the flexion is greater

Patients with a below-knee amputation should be kept on a back-splint with the knee extended for at least three weeks From this stage onwards the patient should be in the charge of the limb-fitters, who will attend to the question of temporary prosthesis, etc , under the guidance of the surgeon

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SECTION XVI

OTORHINOLARYNGOLOGY IN RELATION TO WAR INJURIES

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CHAPTER LXX

INJURIES TO THE EAR IN WAR

WOUNDS AND TEARS OF THE EXTERNAL EAR

THERE may be degrees of damage varying from clean cuts or tears to destruction of the whole of the ear In the former case careful suture with eyeless needles carrying silkworm gut will give good cosmetic results If large defects of tissue have been produced plastic operations are required the details of which are given elsewhere

Infected wounds have special dangers in this region owing to the possibility of perichondritis if this occurs there may be loss of most of the cartilaginous framework with subsequent contraction and deformity necessitating repair by plastic methods. The line of treatment followed by the writer is excision of infected cartilage with a margin of healthy tissue by this means it may be possible to prevent gradual extension with melting away of wide areas of cartilage

HÆMATOMA AURIS

Non penetrating wounds cause effusion of blood with danger of infection and subsequent deformity The result of such an accident appears in civilian life as the cauliflower ear of boxers

The collection of blood should be removed by aspiration or by incision under strict aseptic conditions

INJURY OF EXTERNAL MEATUS

Gunshot wounds may injure the cartilaginous or the bony meatus as well as inflicting other external damage Lacerated skin edges must be excised sparingly particularly if infected purification is carried out with biniodide of mercury in spirit

Syringing must be forbidden in case there is a more deep-seated injury that will allow infected material to be carried into the middle ear or worse still into the internal ear or meninges

Removal of débris and bony fragments is carried out by means of a hook or curette general anæsthesia may be required Attempts to restore or maintain asepsis subsequently are made by the local use of sulphanilamide powder or the instillation of drops of mercury perchloride (1 4 000) in glycerine twice daily if suppuration has commenced a short course of sulphonamide therapy by mouth is desirable

The missile may have penetrated the mastoid process or the direction may be such as to fracture the roof of the meatus or middle ear thus throwing the meninges into communication with the exterior Cerebrospinal fluid will escape from the ear in such cases if the dura is torn (see Fig 793 p 795)

The injury is more marked in the ear directed towards the site of explosion (Fig 791 (5, 9 11)) If bilateral it is the nearer ear which suffers the greater damage. The injury may be bilateral and symmetrical if the subject is in a closed room, a shelter or a dug-out.

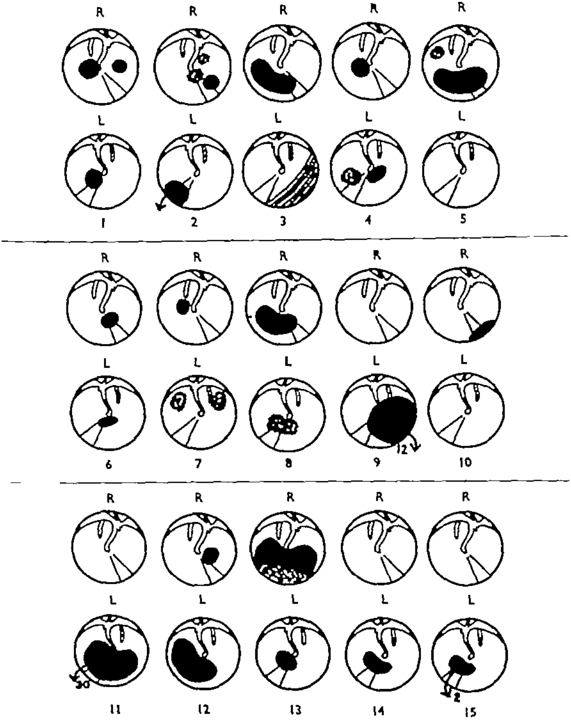

FIG 791

Traumatic perforation of tympanic membrane. The right membrane of each patient is above and the left below Perforations are shown in black and hæmorrhages mottled, with irregular outline. Arrows indicate discharge, the numbers by them denoting duration in days before cessation of infection. The dark area in 3, L illustrates effusion. Further description is in the text.

It is possible for the facial nerve or the internal ear also to be damaged, these complications will be referred to later

If the wound is deep the result may be fatal, from intracranial complications

In the cartilaginous portion, healing by granulation has the disadvantage of contraction with atresia, it is important, therefore, in addition to other measures, to prevent narrowing by the application of silver nitrate (10 per cent) or pure chromic acid to granulating areas

It is sometimes necessary when sepsis has subsided to employ skin grafting, not only externally but also to restore the lumen of the meatus to its original size The graft is held in place on a mould

If the bony meatus is damaged, it is essential to remove detached fragments of bone, pieces of metal, soil or other débris as early as is convenient An operation for removal of cells in the mastoid process, with removal of part or the whole of the posterior meatal wall, may, at a later date, be required as a means of widening the meatus, it may be possible to conserve the tympanic membrane and ossicles

INJURIES OF THE MIDDLE EAR

Damage to the middle ear in warfare may be caused by changes of air pressure or by the penetration of extraneous objects and missiles

INJURY BY CHANGES OF PRESSURE

Causation—During the 1914-18 war and still more in the present, many cases of this type have arisen, the development of high explosives has increased the incidence

The change of pressure causing damage is usually in the positive direction and may be brought about in several ways A blow on the ear can rupture the membrane by propagation of a wave of compression, similar to a pneumatic ram The blow can be given while the meatus is full of water, as in the case of a swimmer who receives a kick on the ear, the membrane may then be torn away over half its attachment

Sudden changes of altitude may cause damage varying from simple hyperæmia to rupture of the membrane Cases are reported in workers under increased pressure in caissons, more occur in airmen, particularly when power diving with inefficiently acting Eustachian tubes Injury to the ear is not necessarily associated with all such sudden dives, provided the air pressure on the two sides of the tympanic membrane is equalized by opening of the tube, swallowing efforts may be necessary to adjust the pressure

An important factor is blast, either from the explosion of a gun or a high-explosive shell or bomb Bursts of sharp and sudden type produce the most damage, such as those produced by light 3 5, by 4 7 or 6 in guns and by high-explosive aerial bombs Associated with the blast, there may be effects due to wind pressure also Blast is equally distributed in all directions, while the effects of wind are felt only in the direction of the projectile

Blast consists of two phases, one short and sudden, of positive type, due to compression of air, and a second, of longer duration, from rarefaction during the stage of recoil The former is of higher degree than the latter, but either can cause injury For example, the walls of a house sometimes fall outwards when subjected to blast, and a window may first bulge in and then burst outwards towards the site of explosion

In the case of the tympanic cavity, it appears that the effects are due to the compression wave, this supposition is supported by comparison with the known effects of blast on the lungs

The direction of the wave, whether of compression or rarefaction, reaches the tympanic cavity by one of two routes That through the external auditory meatus is the shorter and more direct, although of a somewhat tortuous nature in most individuals The second, by way of the nose and Eustachian tube, is longer, narrower and more devious Wind pressure effects would be felt mainly, if at all, through the former route

type There may be high pitched tinnitus of temporary or possibly of persistent character although this symptom is not universal

Swallowing may cause disappearance of these symptoms in slight cases

If the damage is considerable pain is felt but this is usually slight and transient

Giddiness may be noticed, possibly associated with nausea or vomiting and followed by staggering or even falling

It is noticeable however that many patients even with ruptured tympanic membranes do not experience any marked aural symptoms possibly because their attention is otherwise occupied

Deafness in varying degrees follows the injury In cases of clean-cut perforation of the membrane it is usually slight where there is effusion into the tympanic cavity without rupture of the membrane it is more obvious

Sometimes the first and possibly the only obvious abnormality noticed by the patient is the presence of blood at the entrance of the external auditory meatus he may feel some abnormal sensation in the ear and on putting his finger up to ascertain the cause notices that it is blood stained.

If the membrane is perforated air may be heard by the patient whistling through when he blows his nose to this symptom he will pay particular attention

Clinical signs—The injury to the ear is often overshadowed by other and more severe damage elsewhere either as the result of blast or from direct injury The patient may suffer from concussion and remain unconscious for some hours It is important that the damage to the ear should be discovered and dealt with at an early date and therefore it is wise to examine the ears in any suspicious case An electric auriscope is convenient for the purpose

In mild cases there is no more than dilatation of vessels radiating down the handle of the malleus and over the surface of the membrane Depression is present in some cases from obstruction of the Eustachian tube

Effusion is seen as a dark area behind the membrane with a concave or possibly a straight upper limit (Fig 791 (3 L)) If the patient has lain in bed after the accident the line of fluid is horizontal when he reclines and oblique when he sits up Darker areas in the zone of effusion indicate collections of coagulated blood

More severe damage is recognized by the presence of dark blood in the external auditory meatus or on the surface of the tympanic membrane (Fig 791 (2, 7 8))

Perforation is common but may at first be difficult to define owing to the presence of coagulated blood which closely resembles dark cerumen

When the perforation is extensive it may be possible to detect clotted blood in the tympanic cavity (Fig 791 (13 R))

The perforation appears as a round or elliptical defect usually with a clean-cut margin (Fig 791 (1 6 14)) but in other cases with rolled-over red and thickened edges sometimes inverted or everted (see Fig 792) The rupture is seldom marginal In a few instances, however there is a linear rent or even tearing away of the membrane from the tympanic ring possibly over a quarter of its circumference The detached segment flaps with changes of pressure applied through Siegle s pneumatic speculum Many cases show remarkable absence of reaction the perforation resembling one of some years

Pathology—Changes of pressure may do no more than produce dilatation of vessels on the tympanic membrane With greater intensity of action there is general hyperæmia in certain areas, with outpouring of sanguineous secretion into the tympanic cavity, this effusion is probably due to rupture of vessels

The effused secretion collects behind the membrane in the most dependent part, varying with the position of the patient (Fig 791 (3))

If the injury is more severe, the tympanic membrane gives way, either at some spot on its surface (Fig 791 (14, 15)) or at its attachment to the tympanic ring (Fig 791 (13, R)) In cases of shell or bomb blast the former is the more common type of damage

It is surprising to note the limited degree of pathological change in many instances the untorn segments being of normal colour, with almost complete absence of reaction in their blood vessels

The limited area of the tympanic membrane which gives way, and the clean-cut appearance of the margins of the perforation, are reasons for believing that the damage is effected by a narrow column of compressed air, concentrated in part by the funnel shape of the external auditory meatus The margins of the perforation are sometimes everted, presumably by the suction action of the wave of diminished pressure

If the rupture were entirely due to suction action, the effects might be expected to be diffused over a wider area, with probable detachment of the membrane from the tympanic ring

Prevention—With the above considerations in mind, it follows that an efficient method of prevention is reduction of the lumen of the auditory meatus This is sometimes naturally effected by a plug of cerumen of a size sufficient to cause considerable, although not necessarily complete, obstruction

The wearing of tubular vulcanite or hard rubber ear defenders, the aperture in one type being covered with fine-meshed metallic gauze with an intervening diaphragm, is said to give good protection against blast without interfering with powers of hearing A variety of sizes must be available An adjustable plug of soft rubber or some material similar to plasticine, preferably with a groove on one side, to prevent rise of pressure on insertion, is effective, although those made of oversoft material are difficult to insert correctly

The wearing of cotton-wool plugs, smeared with soft paraffin, may be expected to give some degree of protection, although to a lesser extent

To protect the ear against pressure waves due to the disruptive effects of blast, the plug must fit tightly, there is then the disadvantage of reduced hearing capacity for speech, which makes communication difficult Moreover, the insertion of a tightly fitting plug will depress the tympanic membrane by raising the air pressure in the external meatus

Ear plugs may drive cerumen into the deeper parts of the meatus, from which it may subsequently require removal, plugs of wool may be lost temporarily, until retrieved after otological examination

Irritation of the meatus by prolonged wearing of plugs should be prevented or relieved by the application to the surface of the obturator of thick oil consisting of unguentum hydrargyri nitratis dilutum (1 5, 1 drachm) and ol amygdalæ (1 oz)

The mouth should be kept open when exposed to blast, to allow a compressing wave to enter through the *Eustachian tube to counterbalance the pressure in the tympanic cavity* to a certain extent

The ear defenders referred to are not effective against the upsetting low-pitched rumble associated with explosions

Symptoms—Sudden changes of pressure applied to the tympanic membrane produce a sudden sharp noise in the ear, sometimes of an explosive

application of alternate suction and compression enables pus or bubbles of air to be drawn through the perforation thus defining its position and extent

Some cases of rupture due to blast have débris earth, oil or other substances in the meatus as a coincident although not necessarily as a causative factor

Progress—If correctly treated the majority of cases should follow an afebrile and uninfected course Blood is gradually absorbed from the tympanic cavity or else is removed by ciliary action

Linear tears heal rapidly without cicatrization and a perforation even if extensive may close (Fig 792 (D)) A thin cicatrix is formed by the epidermal and mucosal layers in such a case the middle or fibrous layer does not regenerate

Some untreated cases, or those improperly dealt with may progress to infection of a mild and usually afebrile type

Backward spread to the mastoid antrum and air cells is a possible, although luckily an unusual complication

The presence of nasal or nasopharyngeal sepsis is a factor predisposing to infection of the middle ear

TREATMENT

MAINTENANCE OF ASEPSIS—The primary desideratum is to prevent infection of the tympanic cavity This is normally sterile and so is the deep part of the external auditory meatus Infection may enter by one of two routes the external meatus or the Eustachian tube The former harbours bacteria at its entrance where hair follicles and cerumen give a home to many organisms including some of pathogenic propensities This region must therefore be purified by thorough cleansing combined with removal of cerumen.

In our opinion it is advisable to use a solution of biniodide of mercury in spirit in a strength of 1 500 The external ear and entrance of the cartilaginous meatus are carefully purified cerumen being removed by means of a small hook or a wool-tipped probe soaked in the antiseptic solution this procedure presents some difficulty and must be carried out under direct vision by some one of experience

Fluid should not be allowed to enter the deep meatus or to pass into the middle ear dryness of these regions is a powerful factor in maintaining asepsis In this respect the dehydrating effect of alcohol on the skin is of particular value

If the meatus contains infected débris, it is necessary to clear it under direct vision using a wool tipped probe or a small wide-angled hook (Cawthorne s pattern)

Uninfected blood clot should be left alone, it does no harm and will slowly disappear Attempts to remove it will only force some back into the tympanic cavity through the perforation, whence it cannot be expelled infection may follow its introduction

Syringing must be forbidden absolutely There is considerable danger of infecting the middle ear and, if a fracture of the base of the skull, with tearing of the dura is present bacteria may be carried into the subdural spaces

duration Previous attacks of inflammation are undoubtedly the cause of the rupture in a certain proportion of patients, in whom there has been a persistent perforation or a friable cicatrix The position of the perforation is usually in the inferior segments and, in our experience, more often anterior than posterior (Fig 791 (1, 2 6, 12, 13, 14, 15)) The reason would appear to be that the antero-inferior segment lies over the Eustachian tube, blast is able to drive the membrane inwards into this unsupported area and thus to tear it (Fig 791 (2, L, 10, R 12)) Other parts of the membrane are

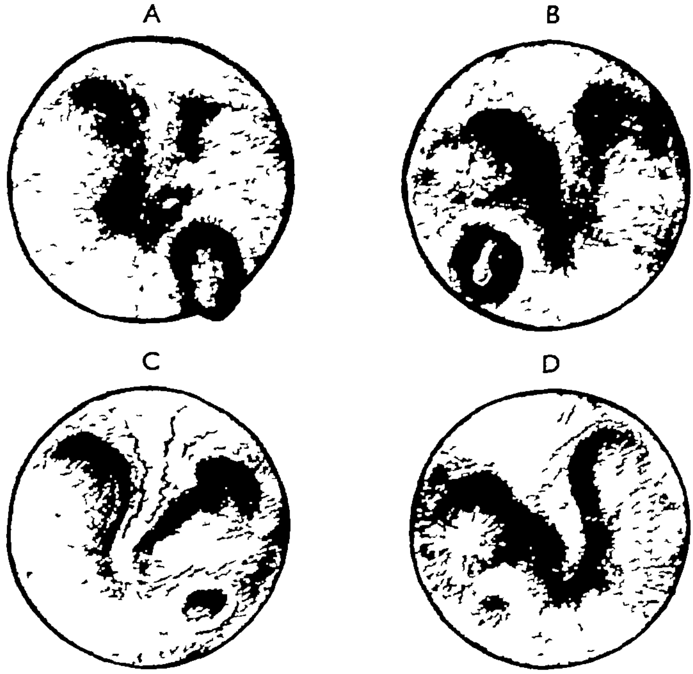

Fig 792

Traumatic rupture of tympanic membranes with infection A and B show the condition two months after injury by a land mine C and D were made six weeks later, when the ears were dry and the perforations healing

driven against the promontory or are partially supported by a cushion of air between the inner and outer walls of the tympanic cavity

Alternatively, if the rupture was due to the suction wave the effect would be more readily felt over the Eustachian tube than elsewhere, the wave of rarefaction in the short external meatus must precede that passing through the Eustachian tube The pull towards the auditory meatus might well coincide with the push of the compression wave, arriving rather later through the more lengthy nasal passage

A perforation in the superior segment of the membrana tensa or in the membrana flaccida is probably due to previous inflammatory changes and is not attributable primarily to injury

Deafness is of middle-ear type as recognized by the negative Rinné sign and by localization of a tuning fork applied to the vertex, towards the more seriously affected side

The question of associated damage to the internal ear will be dealt with later

Cases of some duration may show signs of infection, with collection of muco-purulent or purulent secretion in the meatus (Fig 792 (A, B)) The use of Siegle's pneumatic speculum is of considerable advantage, as the

If discharge persists after two weeks it may be necessary to cleanse the ears by syringing with mercury perchloride (1 4 000 watery solution) care must first be taken to exclude the possibility of fracture of the base of the skull

Sulphonamide is given for the first few days in cases of suppuration As there may be infection with staphylococci in addition to streptococci or pneumococci sulphathiazole (thiazamide) may be used a swab is taken to determine whether the correct chemotherapy has been chosen

The treatment of spread to the mastoid process is dealt with later

PAIN may be severe at first but seldom persists If the tympanic membrane is intact it is permissible to use drops of phenol (5 per cent in glycerine) Analgesics will however suffice in most cases thus avoiding the possible dangers of infection there are definite contraindications to the instillation of fluid when perforation has occurred

After rupture of the membrane there is no distension of the tympanic cavity and therefore pain is not a prominent symptom

DEAFNESS—In cases where the mobility of the membrane seems to be impaired after healing has taken place the tympanic cavity may be inflated. It is wise however to delay in order to avoid the possibilities of infecting an otherwise sterile middle ear

Eustachian catheterization is employed but never while nasal sepsis is present

Results—Rupture of the tympanic membrane causes some diminution of hearing this is most marked soon after the injury from effusion of blood If healing takes place without intervening sepsis there may be only slight deafness the usual site of perforation being one that does not interfere with the movement of the ossicles or of the posterior and superior segments of the tympanic membrane in the region of the stapes

Nothing can be done actively to accelerate healing Infection will, however delay healing and this will be avoided by continuation of precautions against it

If catarrhal or suppurative otitis media follows perforation the prognosis for hearing is not so favourable owing to the probability of adhesions in the tympanic cavity and of partial or complete fixation of the ossicular joints

Spread of infection from the tympanic cavity to the mastoid antrum and air cells—If the simple aseptic precautions detailed above are carried out assiduously and for a sufficiently long period the incidence of otitis media will be low and consequently infection of the mastoid antrum and air cells will be rare

If backward spread of infection does occur with retention of inflammatory secretions in mastoid air cells possibly associated with the formation of granulations suppuration may continue indefinitely the more so if there is breaking down of intervening cell walls with the production of coalescent cavities The process is usually afebrile and painless but possibly there may be tenderness over the mastoid antrum and tip of the mastoid process associated with pyrexia and aural discharge Sulphonamide therapy may be effective in acute or subacute cases in leading to subsidence without operation lack of necessity is one reason therefore for postponing operation

In cases of traumatic rupture, syringing is ineffective, as it merely drives bacteria inwards and cannot possibly cleanse all the recesses of the middle ear

For similar reasons the use of antiseptic drops in uninfected cases is contraindicated

A plug of sterile wool is inserted into the affected ear, it is changed twice daily, and before replacement the external ear is swabbed with spirit

If a complicating fracture of the base is suspected, a larger sterile dressing and bandage are used

Infection through the Eustachian tube is unlikely unless there is sepsis in the nasopharynx It is essential in all cases to warn the patient against forcible blowing of the nose, especially if he suffers from rhinitis If it is necessary to clear the nose, only one nostril must be closed at a time and no force used Sniffing is probably safer as a means of removing secretions

If rhinitis is present, steam inhalations are given two or three times daily, a solution of menthol (3 gr) with tinct benzoin co (1 drachm) in a pint of steaming water is satisfactory

Infection of the paranasal sinuses requires investigation and suitable treatment

Nasal douching must be forbidden in all cases

A full prophylactic course of sulphapyridine (M & B 693) should be given for three days in cases with perforation

EFFUSION WITHOUT PERFORATION—The presence of fluid in the tympanic cavity requires the precautions outlined above The absence of obvious *perforation is no reason for relaxation of attempts to maintain asepsis*

Hæmorrhages on the tympanic membrane are similarly dealt with, their presence *may hide a rent in the tympanic membrane, through which infection may enter, especially if they are disturbed by manipulation*

An effusion will probably absorb or be removed by ciliary action If still unchanged after two or three weeks, and if hearing is much impaired, inflation with a Eustachian catheter may be employed Paracentesis is not required to expel the fluid, the danger of infecting a sterile collection of fluid is a strong reason for avoiding this operation

INFECTION OF TYMPANIC CAVITY—If the precautions detailed above are carried out sedulously, practically all cases will follow an aseptic course *Neglect or undue interference will undoubtedly lead to infection in a* proportion of cases, by allowing, or even encouraging, entrance of bacteria into an otherwise sterile tympanic cavity

If infection has taken place before the case is seen, different treatment must be adopted

There will be discharge of muco-purulent or purulent type, possibly blood-stained Pain or tenderness are unlikely signs, the infection generally runs an afebrile course and does not take on the characters of acute otitis

Fig 792 depicts such a condition The patient had well established suppuration on admission to hospital *Progress was slow and was retarded by chronic rhinitis* The eventual result was satisfactory

Discharge is removed by gentle mopping and not by syringing, during the first two weeks of its course *Drops of perchloride of mercury* (1 4,000 in glycerine) instilled warm twice daily are recommended

FRACTURE OF BASE OF SKULL INVOLVING MIDDLE EAR

The fracture line may pass through the roof of the external meatus or may involve the mastoid antrum or tympanic cavity (Fig 793) Bleeding from the ear is characteristic and is in most cases an indication that the tympanic membrane is torn thus allowing escape of fluid from the middle ear

If the dura mater is torn there may be escape of cerebro-spinal fluid, appearing as a watery discharge from the ear at first blood-stained and subsequently clear

The injury is not of itself of such immediate danger as is the risk of subsequent infection and meningitis

Syringing must be absolutely forbidden as being an effective means of precipitating intracranial infection It is advisable to give definite orders that no injured ear is to be syringed without specialist opinion and consent

The external ear and entrance of the meatus must be purified efficiently It is essential not to attempt the immediate removal of blood clot but any extraneous débris must be gently scooped or mopped out A sterile dressing is applied to the ear and kept there for ten to fourteen days at least

In most cases the cleft in the base heals and no more cerebro-spinal fluid appears Even in cases with no injury to the dura the fracture line may remain open there is then a probability of subsequent inward spread of infection if otitis media develops even after the lapse of years A radical mastoid operation is indicated in such cases

Results—The degree of deafness if any will depend on the extent of injury to the tympanic membrane on fixation of ossicles and on the possibility of involvement of the cochlea a question to be discussed later

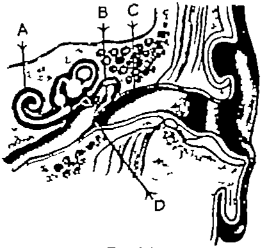

FIG 793

Semi-diagrammatic figure to show the sites of involvement of the ear in fractures of the base of the skull.

A, Cochlea The other parts of the internal ear may be affected in any case all parts of the perilymph and endolymph symptoms are involved.

B Middle ear The fracture line may pass through the tegmen tympani or tegmen-antri. The tympanic membrane is liable to rupture in the antero-inferior or anteroposterior segment as illustrated at D

C, External auditory meatus A fracture here does not necessarily lead to infection, as this region is normally sterile and will remain so under appropriate treatment

(*Adapted from Cunningham "Textbook of Anatomy."*)

COMPOUND FRACTURE AND PENETRATING WOUNDS OF THE MASTOID PROCESS

A metallic projectile or a foreign body such as a piece of wood or a stone may fracture or enter some part of the mastoid process There may be associated rupture of the tympanic membrane The cardinal symptoms are shock and possibly loss of consciousness usually followed by deafness

There is a further factor, however, that must influence the surgeon in deciding the question of operation, and that is the danger of early interference It must be stated dogmatically that an operation for uncomplicated acute mastoiditis should not be performed sooner than ten days after the onset of infection , the optimum period is during the third week

The patient, if he develops high temperature, must be treated during the first two weeks as a case of septicæmia

Sulphonamide is given in full doses usually for three, but possibly for eight, days 4 tablets (2 gm) of sulphapyridine (M & B 693) as a commencement and 2 tablets (1 gm) four-hourly afterwards , if vomiting is caused by oral administration, a change may be made to sulphathiazole (thiazamide) or to intramuscular injections A swab is taken to determine the nature of the organisms if streptococci alone are present sulphanilamide (prontosil) may be prescribed

After three days, and again after one week, a blood examination is made to exclude leukopænia If this occurs, injections of pentose nucleotide (0 7 gm intramuscularly) are given daily for three or four days

Secondary anæmia is treated by one or more transfusions of blood , and, for severe toxæmia, injections of antistreptococcal serum (20 to 50 c c of anti-scarlatinal serum) are required

The only indications for a mastoid operation before the end of the second week are (*a*) a subperiosteal or subcutaneous abscess behind the ear or in the zygomatic region, (*b*) infected thrombosis of the lateral sinus, as evidenced by rigors and tenderness in the neck

If suitable treatment is carried out the general condition of the patient should improve and the discharge from the ear should become thicker as reaction appears An operation at this stage will be found to proceed smoothly, with absence of complications and with firm healing

The cases that require operation are few in number, and in the majority there is an absence of acute signs or symptoms

PENETRATING WOUNDS OF TYMPANIC MEMBRANE

There is little difference between wounds of this type and those due to sudden changes of pressure The symptoms are similar The diagnosis is made by the appearance of blood in the external meatus and by the discovery of the causative foreign body

The *perforation tends to be ragged at its margins and not clean-cut,* as in nearly all cases of blast

There is likely to be diffuse hyperæmia of the tympanic membrane

Associated injuries of the external ear, the external meatus, the mastoid cells, or the internal ear add to the gravity of the prognosis and call for appropriate treatment

After the external ear and meatus have been purified as described above, any foreign body should be removed, *if necessary under general anæsthesia*

The insufflation of sulphonamide powder or the instillation of drops of mercury perchloride in cases already infected (1 4,000 in glycerine) are of use in combating sepsis

The treatment is in general similar to that of rupture due to blast

FRACTURE OF BASE OF SKULL INVOLVING MIDDLE EAR

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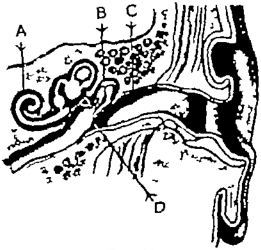

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B, Middle ear The fracture line may pass through the tegmen tympani or tegmen-antri. The tympanic membrane is liable to rupture in the antero-inferior or anteroposterior segments as illustrated at D

C, External auditory meatus: A fracture here does not necessarily lead to infection, as this region is normally sterile and will remain so under appropriate treatment

(Adapted from Cunningham "Textbook of Anatomy")

The external ear and entrance of the meatus must be purified efficiently It is essential not to attempt the immediate removal of blood clot but any extraneous débris must be gently scooped or mopped out A sterile dressing is applied to the ear and kept there for ten to fourteen days at least

In most cases the cleft in the base heals and no more cerebro-spinal fluid appears Even in cases with no injury to the dura the fracture line may remain open there is then a probability of subsequent inward spread of infection if otitis media develops even after the lapse of years A radical mastoid operation is indicated in such cases

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and sometimes by vomiting and vertigo, with signs of nystagmus or facial paralysis, according to the site and extent of injury

It is desirable to operate as early as possible after treatment of shock and preparation of the patient The affected area is widely shaved and the skin is purified, first by scrubbing with ether soap and then by swabbing with ether, followed by biniodide of mercury in spirit The edges of the wound in the skin are excised if severely bruised or lacerated, loose fragments of bone and any extraneous objects or débris are removed, and hæmorrhage is arrested

Opinions differ as to how much more should be done, some authorities recommend the opening of all the mastoid air cells

Our own advice is conservatism, provided the above recommendations have been carried out

Bone edges are smeared with iodoform to prevent osteomyelitis, the wound is lightly packed with iodoform gauze or with sulphonamide No extensive operation is performed at this stage The skin is left unsutured and freely open, a full course of sulphonamide therapy is given for three days, or more if there is pyrexia

After the lapse of at least ten or preferably fourteen days, a more extensive removal of the air cells is carried out It will probably be necessary to perform a clearance similar to the cortical mastoid operation, but the extent of the wound may necessitate extension of the operation in various directions, possibly beyond the margins of the external auditory meatus

In the last war the mortality from wounds of the mastoid process was high, the introduction of chemotherapy should now diminish the gravity of this type of injury

INJURY TO FACIAL NERVE

In certain cases paralysis of the facial nerve is present, if the injury is severe it will cause complete paralysis of one side of the face, and recovery may be in doubt The nerve may be damaged in its canal, if the injury is high up in its course there will be loss of the sense of taste in the tongue on the injured side, from involvement of the chorda tympani nerve

The damage may, on the other hand, be inflicted on the nerve after it has left the stylo-mastoid foramen, and only one branch may be affected

Spontaneous recovery follows in some cases, but if there is delay it may be decided to expose the nerve, this procedure should lead to recovery unless there is an actual gap In such a case a graft taken from the external cutaneous nerve of the thigh must be inserted to restore continuity

If division has taken place outside the skull, direct end-to end suture may be possible If the gap in the divided nerve is too wide to allow of direct suture, a graft may be used to bridge the deficiency

TRAUMATIC DISTURBANCES OF THE INTERNAL EAR

Causation—Loss of hearing and other symptoms of internal-ear type occur in some individuals who have been subjected to loud noises, either of temporary or prolonged duration Repeated short, sharp explosions are those most liable to cause damage The discharge of a gun or the burst of a shell or bomb may be the causative factor, a similar result may be produced by the noise of a shot-gun, as noticed in some who have shot consistently for years

As with injury to the tympanic membrane, so in this condition the ear nearer to the explosion suffers more; game shots notice symptoms more markedly in the left ear if they fire from the right shoulder Not only may concussion effects, arriving through the external meatus, cause signs and symptoms, but similar injury may be due to transmission of violence through the skull from neighbouring regions such as the occiput, as the result of a blow

Pathology—The perilymph and endolymph systems are severally continuous throughout the divisions of the internal ear through semicircular canals, utricle saccule and cochlea. It follows, therefore, that symptoms and signs appear in the various components, arising from a common cause although there is evidence to show that the organ of Corti is more susceptible to pressure changes than the vestibular end organ There may be actual damage to the auditory nerve from minute hæmorrhages or from œdema; in extreme cases there are no doubt hæmorrhages or effusion into the perilymph or endolymph systems, or possibly damage to the sensitive fibres of the cochlea or ampullæ of the semicircular canals.

It is known that patients who have suffered from the effects of blast, without external injury may have blood in the cerebro-spinal fluid system or hæmorrhages in the lungs.

The possibility of effusion of blood into the labyrinth is, on this evidence beyond dispute

Symptoms—Slight traumatism may do no more than depress the function of hearing while at the same time producing tinnitus of high pitched type this is usually more marked in one ear More severe injury particularly if there is hæmorrhage into the labyrinth or damage in other neighbouring regions gives rise to symptoms of shock followed by vomiting with vertigo and instability The patient will later be unstable in walking but will gradually recover his equilibrium Symptoms such as these might at first sight be attributed to injury of the cerebellum, in otitic cases the associated deafness suggests the correct diagnosis.

Signs—Examination may fail to reveal signs of injury to the middle ear the tympanic membrane being unaffected and the Eustachian tube unobstructed There may on the other hand be associated lesions in the external or middle ear or in the neighbouring regions of the skull.

Deafness is of internal-ear type with greater diminution of perception for high than for low tones This makes the hearing of a whisper relatively more difficult than that for ordinary conversational voice owing *to the* sibilant character of the former

The usual characteristic of internal-ear deafness is present, namely diminution of absolute bone conduction A tuning fork of 256~ is repeatedly applied to the mastoid process until no longer perceived by the patient, whose external auditory meatus must be closed. Comparison is made with a normal individual, whose meatus also is closed. Shortening of the period of perception indicates diminution of cochlear function. Weber's test is also useful a tuning fork held on the vertex is heard more loudly in the better ear

Tests can also be carried out with a monocord and an audiometer With the former the high tone limit is found to be depressed, while the latter shows relatively greater *diminution* of perception for high tones. There may be a sudden drop, perhaps at the 4,000~ level.

If the internal ear is completely out of action, no sounds at all are perceived, whether produced by a tuning fork or by the raised voice.

In cases of severe unilateral internal-ear deafness it is essential to mask the good ear by means of a noise box when testing for hearing function in the damaged ear Otherwise the good ear may perceive the sounds intended for the affected ear and a false impression of the hearing capacity will be produced.

As regards the function of orientation there may be depression on the more severely affected side, particularly if there is effusion into the labyrinth unbalanced stimuli from the good ear cause sensations of vertigo and inco-ordination. Signs of nystagmus and past pointing are present.

It would be possible to investigate the functions of the semicircular canals by caloric and rotation tests. It is, however unnecessary to carry these out in the early stages of traumatic cases. All the information required can be obtained by *testing the cochlea*, and by noting any signs and symptoms of vestibular damage, as, for example, spontaneous nystagmus, past pointing and vertigo.

It may be necessary to distinguish between injuries of the internal ear and those of the cerebellum. Investigation of the cochlea and eyes, and tests of co-ordination will establish the correct diagnosis.

Complete deafness of functional type is sometimes met with, causing difficulties in differential diagnosis.

Prognosis—Traumatic internal-ear deafness of incomplete type may recover, even if effusion has taken place , complete loss of function will, however, never improve

Tinnitus of severe type usually disappears, but a high-pitched hiss may persist

Vertigo and instability disappear entirely, but sometimes only after the lapse of several months

Treatment *is ineffective in restoring hearing, but something can be done* to relieve other symptoms Luminal is useful in ameliorating tinnitus and vertigo , scopolamine may be tried in severe cases Bromides will diminish tinnitus, but their depressing effect is a drawback

FRACTURE OF BASE OF SKULL INVOLVING THE INTERNAL EAR

A fracture into the labyrinth causes hæmorrhage and disturbance of the perilymph and endolymph systems (Fig 793, p 795) Complete deafness of internal-ear type is to be expected Vertigo is produced, but if the patient recovers it disappears later, when accommodation to the stimulation of a single labyrinth has been established

If the fracture extends, in addition, into the middle ear and otitis media is present, there is danger of labyrinthine infection , and if the external auditory meatus is thrown into communication, owing to rupture of the tympanic membrane, the danger of inflammation is still greater In such cases there may be escape of cerebro-spinal fluid from the ear

Treatment consists in maintaining strict asepsis of the external ear and auditory meatus, and in avoiding syringing , it also entails the prevention of spread of infection from the nasopharynx by treatment of rhinitis, and also by avoidance of nose-blowing or of nasal douching Sulphonamide treatment is essential in all such cases

PENETRATING WOUNDS OF INTERNAL EAR

The entrance of pieces of metal or of fragments of bone exposes the internal ear to great danger of labyrinthitis, followed by meningitis Foreign bodies must be gently removed, particularly if of septic nature Mopping away of infected débris is carried out under vision, but syringing is prohibited If infection of the middle ear arises, drops of perchloride of mercury (1 4,000 in glycerine) are instilled two or three times daily , sulphonamide is given in full doses

The cochlear and vestibular functions are deranged or destroyed by such an accident Symptoms of shock and concussion are present, followed by vomiting, with vertigo and nystagmus

If the patient recovers, he will experience instability when beginning to walk, but will gradually accommodate himself to changed conditions

COMPLICATIONS ASSOCIATED WITH INJURY TO THE EAR

Osteomyelitis—The opening up of diplöic bone always has the possibility of leading to osteomyelitis

This complication is most likely to occur if fresh bony spaces are exposed to acute local infection After ten or fourteen days reactionary processes shut off the diploë and prevent the spread of bacteria

It should be a principle therefore to eliminate sepsis from the wound at an early date and certainly within forty-eight hours after infliction, by excision of the edges of the wound and the removal of foreign bodies and detached fragments of bone combined with thorough purification of the surrounding areas of the skull

If this desirable result cannot be attained at an early date then any operation on the bone must be postponed until natural defences have been established

At the time of operation it is in our opinion desirable to smear freshly cut bony margins with iodoform to prevent bacterial spread

If osteomyelitis is diagnosed operation must be immediate and drastic

Thrombo-phlebitis—Infected wounds in the neighbourhood of the lateral sinus may lead to the formation of a mural clot or of lateral sinus thrombosis, characterized by rigors. *Treatment* is directed to stopping the local venous circulation by obliterating the lateral sinus and ligaturing the internal jugular and communicating facial veins.

Extradural abscess—Spread of infection may cause granulations to form on the dura mater with symptoms of dull headache, or it may cause pus to collect outside the dura with headache often more noticeable at night-time A collection of pus outside the dura is likely to cause meningeal reaction with signs of increased intracranial pressure

TREATMENT is directed to free exposure of the affected area bone is removed in the region of the tegmen antri or tympani until healthy dura is reached in all directions A light packing of iodoform gauze is then applied

Meningitis—Any wound penetrating the dura mater may cause meningitis Other aural causes are perforating wounds of the internal ear or fracture of the base of the skull with tearing of the dura

Spread of infection from the middle ear may also lead to this serious complication

The temperature is high the pulse is rapid and the patient is restless. White cells are present in the cerebro-spinal fluid and bacteria may sometimes be recognized in cases of diffuse and purulent meningitis

TREATMENT depends primarily on the destruction of the causative bacteria by chemotherapy the drug generally used is sulphapyridine (M & B 693) unless culture of organisms points to the preferability of prontosil (sulphanilamide) or sulphathiazole

It is important to avoid spreading infection by operation the results of surgical treatment before the introduction of sulphonamides were extremely bad no benefit but only harm accrues from the opening up of fresh areas of sepsis

The cerebro-spinal fluid is examined for pressure and cell content The presence of headache is a good clinical guide A check is kept by means of lumbar puncture performed at least once a week pressure is lowered if necessary by removing some fluid through the needle or by dehydration with concentrated magnesium sulphate (6 oz. of 50 per cent solution) given rectally once or twice daily

Serous meningitis may be secondary to a brain abscess, which must be drained

Encephalitis results from infection in a penetrating wound, when there is tearing of the dura and laceration of the brain Such a condition may complicate some wounds in or around the ear

If localized, the infection may disappear under treatment without leaving after-effects but if diffused, the prognosis is serious

Localized inflammation of the brain tissue is dealt with by strenuous efforts at removing sepsis from the overlying wound Lacerated or infected skin edges should be excised and comminuted bone taken away The margins of the bony defect are removed and torn dura is trimmed Destroyed brain is removed by suction The skin margins are drawn together with silk-worm gut stitches but not tightly if any signs of sepsis are still evident in the brain Dressings of hypertonic saline are useful in such cases

Brain fungus is treated by the elimination of local sepsis and by control of cerebro-spinal pressure by dehydration and lumbar puncture

Abscess of the brain may arise as a result of injury or inflammation of the middle ear The site may be in the temporo-sphenoidal lobe or the cerebellum A temporo-sphenoidal abscess may cause paresis or paralysis of the opposite side, whilst a significant sign in left-sided cases is nominal aphasia Cerebellar abscess may cause weakness and inco-ordination on the affected side Not infrequently a brain abscess gives very few localizing signs

The principles of treatment depend first on full use of sulphonamide, secondly on cautious and gradual drainage, to avoid precipitating diffuse meningitis, and thirdly, on the eventual provision and maintenance of free and wide drainage after adhesions have shut off the subarachnoid space

The abscess is generally approached by the route of injury Drainage is effected by the use of Mosher's cone or by King's method of free removal of overlying tissue, to cause the abscess to come gradually to the surface and thus to obliterate the cavity

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CHAPTER LXXI

WOUNDS OF THE AIR PASSAGES AND AIR SINUSES

INJURY OF THE EXTERNAL NOSE

THE framework of the nose may be injured by a direct blow by the impact of a missile or by contact with the ground or some resistant object Of missiles shell fragments are the most common cause of injury with bullets next in order of frequency Flying débris of various sorts and stones are other factors Aeroplane crashes may break the nose a blow at football or boxing incidental relaxations of warfare may be the cause

The cartilaginous portion is sufficiently elastic to regain its original position unless destroyed but the bony framework may suffer displacement or fracture Loss of the middle third of the cartilaginous framework leads to upturning of the tip with pug nosed deformity The cartilaginous tip may be lost with resulting downturning

There may be lateral displacement of the bones with associated movement of the cartilaginous portion towards one side Other cases show flattening of the nose due to backward displacement of the bones, sometimes with their separation

The components involved in simple fractures are the nasal and lachrymal bones and sometimes the ascending processes of the superior maxillæ The resulting deformity varies with the degree and direction of violence

Associated with such fractures may be injury of the septum which is either displaced or broken the accident sometimes produces hæmatoma of the septum (see p 802)

Compound fractures communicate with the exterior directly through some wound of the skin of the nose or indirectly through a tear of the nasal mucosa in the latter event the formation of a hæmatoma is unlikely as extravasated blood is free to escape There may be considerable comminution of bone and fragments may have to be removed either externally or from the nasal fossæ

The whole nose can be blown off by a laterally directed piece of shell or bomb rhinoplasty is required later to repair the deformity one of the most disfiguring possible

Treatment—Gentle correction of the nasal deformity is advisable soon after the time of injury Severe epistaxis may necessitate plugging one or both fossæ it is desirable to use 1-in ribbon gauze well soaked with a mixture of iodoform and soft paraffin Packing the nose is however dangerous if the base of the skull is fractured

When the swelling of the soft tissues has subsided, after three or four

days, bones should be manipulated into place with Walsham's forceps, displacement or fracture of the septum is corrected with Ashe's forceps (see p 297) The shape of the nose is maintained by a splint built up of eight layers of fine gauze, held together by collodion applied to each layer in turn Alternatively, a piece of thin malleable metal is applied to the nose and over this a mould of Stent's material—the latter being used as a splint

If too long an interval be left before replacing the bones, there will be fixation, the safe period during which manipulation can be carried out is up to three weeks After this lapse of time it may be necessary to make incisions within each nasal vestibule and to divide the nasal bones and ascending processes of the maxillæ with a fine saw and chisel, to obtain mobility before resetting

THE NASAL SEPTUM

Pre-existing deviation of the septum is liable to accentuation by injury of the nose, manipulation is generally unavailing and internal splints are not effective Correction of the displacement necessitates removal of septal cartilage and bone by submucous resection

Hæmatoma of the septum calls for incision as a means of avoiding permanent broadening and obstruction, and also to prevent necrosis of the septal cartilage

If infection occurs septal abscess results, with the sequela of considerable deformity through loss of cartilage and contraction of scar tissue The patient must be warned of this possibility

TREATMENT—A long incision is made over the hæmatoma, parallel to the floor of the nose, the scalpel is made to cut through the muco-periosteum from behind forwards

It is essential to maintain asepsis of the nose by preliminary purification of the external skin and cleansing of the nasal vestibules with alcohol, in order to prevent infection of an otherwise sterile hæmatoma A small pad of sterile gauze should subsequently be worn to cover the nostrils, held in place by tapes around the head

NASAL FOSSÆ

Penetrating wounds have a tendency to produce lacerated surfaces on the lateral wall or septum, adhesions follow, with obstruction of respiration and also of aeration and drainage of the paranasal sinuses

Tags of mucosa or semi-detached portions of the turbinal bodies should be removed with turbinal scissors The inferior turbinal must be conserved to the utmost A loose packing of iodoform gauze is necessary if hæmorrhage is severe, but it should be discarded as soon as possible

The daily insertion of a tampon of wool soaked in 10 per cent solution of protargol serves to shrink swollen mucous membrane and to separate adherent surfaces, if adhesions are resistant, they must be broken down with a probe or flat dissector, or divided with scissors after cocainization

FRACTURE OF ROOF OF NOSE

Some fractures of the base of the skull involve the cribriform plate and roof of the ethmoidal cells There is epistaxis, associated with escape of

cerebro-spinal fluid if the dura is torn this secretion is at first mixed with blood and later appears as a colourless, clear nasal discharge Loss of the sense of smell may result from injury to the olfactory nerves

Such fractures are highly dangerous owing to the risk of infection of the meninges

A fracture of the base of the skull may involve the roof of the nasopharynx blood may escape and be swallowed to be vomited later

Treatment—The nose must be purified and protected from fresh infection by the use of a gauze bolster as mentioned above Sulphapyridine is given in full doses for a few days

Plugging the nose should be avoided if possible however if dangerous epistaxis necessitates packing the latter must be confined to the inferior meatus Ribbon gauze must be well impregnated with iodoform it must be changed at intervals usually after twenty four and never longer than forty eight hours

If cerebro-spinal rhinorrhœa persists the constant danger of ascending infection leading to meningitis calls for the insertion of a graft of fascia lata to cover the bony cleft

PARANASAL SINUSES

Frontal sinus—The *anterior wall* of this sinus is exposed to injury and is sometimes fractured

Simple linear fracture is of no great importance depression of the bony wall causes considerable deformity and may call for correction. The possibility of infection within the sinus, and the danger of osteomyelitis or intracranial complications as a result of premature operation point to the wisdom of waiting for ten days before proceeding to correction of the defect.

An incision just below the eyebrow—which must not be shaved—ensures a good cosmetic result The skin and periosteum are divided and the bone exposed. If the depressed wall cannot readily be elevated it may be necessary to make a small opening through the compact and thin floor of the sinus, in order to insert an instrument.

No complications should result, provided aseptic precautions have been taken.

Compound fracture of the anterior wall necessitates excision of ragged or infected skin edges and removal of detached fragments of bone

If the superciliary ridge is preserved deformity is slight Free temporary drainage will be required in septic cases owing to the danger of osteomyelitis application of iodoform to the exposed edges of the frontal bone is a wise precaution against this dangerous complication

Wide damage may make it impossible to preserve the contour of the forehead it may then be desirable to obliterate the frontal sinus At the time of injury no more should be done than to excise severely infected edges of skin and to remove detached bone the wound is lightly packed with iodoform gauze and is left freely open

After an interval of at least two, or better still, three weeks the mucous membrane lining the sinus is removed by curettage and the overlying skin and periosteum are pressed back into contact with the posterior bony wall. Subsequent plastic operations, with the insertion of fat or bone grafts, may be employed to improve the cosmetic result In some instances it is preferable to reconstruct the cavity of the frontal sinus, lining it with a skin graft

Fracture of the posterior wall—Injury in this region is of serious import because of the risk of intracranial infection. A fracture of the cranial vault may involve the posterior wall while leaving the anterior wall intact

In such a case air may be blown into the anterior fossa of the skull, as revealed by radiographic examination.

The nose must be kept sterile and the patient warned against blowing it, no complications need ensue and the cleft should close

But if infection occurs, wide operation is necessary The anterior and posterior walls of the sinus must be removed to expose the dura over the area of infection, it may be possible to preserve the supra-orbital ridge

If the dura is torn by a fracture involving the frontal sinus, there will be an escape of cerebro-spinal fluid into the nose, initial bleeding is followed by rhinorrhœa of a watery character It is wise to give a course of sulphapyridine (M & B 693) for three or four days to control invasion of streptococci or pneumococci

While the clefts in the bony walls and dura are open the danger of meningitis is great, and this complication is almost certain to occur in the *near or distant future It is necessary, therefore, in cases that do not close* rapidly, to perform a radical operation

MAXILLARY SINUS

Hæmatoma—A blow on the face, even if insufficient to fracture bone, can cause hæmorrhage within the antrum of Highmore

The *nature of the complication is recognized by the history of injury* associated with nose bleeding, and by the evidence of rhinoscopy, transillumination and possibly radiography

There is no reason for infection to occur if the vestibule of the nose is kept sterile and surgical interference such as puncture and lavage is avoided

Evidence that the effusion is sterile is afforded by the absence of a history of nasal discharge of purulent or mucopurulent nature, and confirmed by examination of the nasal fossæ.

If left alone the blood in all likelihood will be removed by ciliary action, with no sequelæ If infection unfortunately occurs, the antrum must be washed out with normal saline solution after inserting a trocar and cannula through the inferior meatus

Simple depressed fracture—The anterior *wall* of the maxillary sinus is sometimes pushed inwards, with or without fracture or displacement of the malar bone If uncomplicated and uninfected the fracture of the maxilla is best left alone, unless the deformity is severe

In the latter case, elevation, though difficult, may be attempted through an incision over the front of the maxilla after raising the lip There is danger of infection of the sinus after such an operation, if this occurs, lavage or possibly permanent drainage of the antrum into the inferior meatus of the nose (antrostomy) will be necessary If it is found impracticable to elevate the depression, it is possible to repair the deformity later by subcutaneous insertion of bone, cartilage or fat Sinus infection, if present, must be cured before such a procedure is carried out

Compound fracture—Fractures associated with an external wound, particularly of infected type, require operative treatment Any associated injury to the eye must be treated, severe involvement may necessitate removal of the eyeball or evacuation of its contents

The wound may also involve the cheek, nose, upper lip or lower jaw, immediate replacement of soft tissues in as nearly correct position as possible will reduce *the subsequent contraction* and *will facilitate plastic repair*

The margins of fistulæ should be covered temporarily by sewing skin to mucous membrane

In cases of compound fracture involving one or both maxillary sinuses it is possible that fragments of bone pieces of metal and infected material such as earth have been carried in It is therefore necessary to explore the wound or to open the sinus by the sublabial route (Caldwell Luc operation) so as to remove foreign bodies and to establish free and effective drainage The latter may be through the wound itself or else through an opening into the inferior meatus of the nose Subsequent lavage will be required to remove blood clot and infected secretion

The operation may well be performed soon after the injury but a full course of sulphonamide therapy preferably sulphapyridine (M & B 693) two tablets four hourly should be given during the next three or four days Before the operation is performed preparation of the mouth entails elimination of dental sepsis by suitable treatment If signs of acute inflammation are present the operation should be confined to the minimum required to establish free drainage

Fracture through upper alveolus—Fractures in this region are seldom associated with displacement unless both sides are involved. Aeroplane crashes may cause such an injury by pushing back the central teeth or displacing the premaxilla The palate also may be fractured and displaced. Splinting is seldom required but damaged teeth must be removed

It may be necessary to replace the palate and to hold it in position with a plate with loops protruding from the angles of the mouth. The upper alveolus can also be held in position temporarily by placing a prop between it and the lower jaw the latter being supported by a four tailed bandage Treatment of the maxillary sinus will follow the lines detailed above according to the presence of a sterile effusion of blood or of infection from the skin surface or the mouth.

ETHMOIDAL AND SPHENOIDAL SINUSES

Fracture of the base of the skull may run across the roof of one or more cells thus producing the dangerous condition already referred to of communication of the meninges with the nasal fossæ.

There is nothing further to add to what has already been said.

Penetrating wounds—A bullet or piece of shell may pass through the ethmoidal labyrinth or may lodge in this region Immediately after the injury the wound must be purified Lacerated skin margins are sparingly excised and loose pieces of bone removed the wound is not sutured but is held open with iodoform gauze or a drain no fresh layers should be opened up and no extensive search made for a foreign body (Fig 704)

It is wiser to allow fourteen days or more to elapse before embarking on any extensive surgical procedure for fear of precipitating infection of the meninges or the cavernous sinus by spread of bacteria through communicating veins or through actual bony defects

Search for the foreign body is best made by the route employed in external ethmoidectomy except in rare cases where intranasal operation suffices If the piece of metal is deeply embedded and inaccessible it may be wise to leave it alone unless signs of suppuration ensue

Such a case is illustrated in Fig 704 The foreign body entered at the inner angle of the eye and smashed the walls of anterior and posterior ethmoidal cell It caused infection of these air cell and also of the maxillary and frontal sinuses.

External ethmoidectomy was performed, but the piece of metal was inaccessible and was not removed by this route Its presence caused referred pain and eventually necessitated operation through the posterior wall of the antrum for its extraction The inaccessibility of the region, combined with bleeding from the spheno palatine artery, caused considerable difficulty

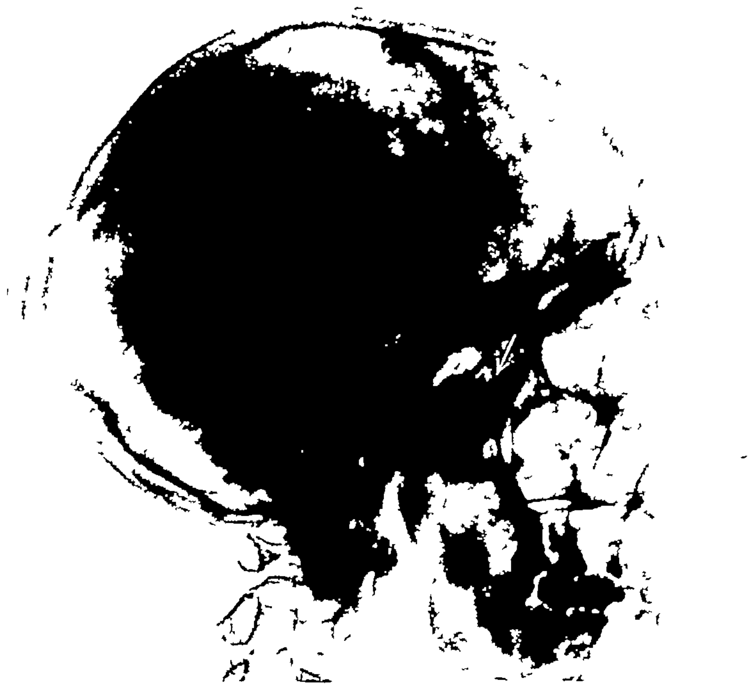

FIG 794
Fragment of high explosive shell, impacted in left pterygo-maxillary fossa

GENERAL EFFECT OF WOUNDS OF THE NASAL SINUSES

With any head wound, *shock* is unlikely to be a prominent symptom Descent of blood into the pharynx or larynx, or the driving in of earth or other débris can produce *suffocation* *Hæmorrhage* may be severe , the blood supply is from branches of the internal maxillary, but in addition wounds involving the face and tongue may implicate the facial or lingual arteries If control by pressure is impracticable or ineffective, it may be necessary to tie the external carotid , this should seldom be necessary

Fistulæ into the sinuses require plastic repair, probably after the interval of three months It is usually necessary to turn in a flap of skin or mucosa, with an epithelial surface facing inwards and to cover this with a skin flap, slid or swung over according to the situation Such fistulæ between the mouth and maxillary sinus are difficult to close if at all large , it is unwise to leave them open, however, owing to the certainty of repeated reinfection

Operations should not include removal of any palatal alveolus

As already mentioned, it is essential to eliminate dental sepsis as a preliminary to operations in this region

LARYNX

EXTERNAL INJURY WITHOUT FRACTURE

This type of accident may happen if the individual falls against a bar, as, for instance, the framework of a motor-car windscreen Aeroplane

crashes are also possible causes of this injury The larynx is well protected, however the impact of such accidents being taken by the lower jaw and sternum

Falls or blows on the larynx may produce submucous œdema or hæmorrhage Owing to the firm attachment of the epithelium over the vocal cords which bound the narrowest part of the airway it is improbable that marked obstruction of the glottis will occur or that dyspnœa of a dangerous degree will arise the necessity for tracheostomy is therefore unlikely to arise

Injury to the laryngeal cartilages can cause perichondritis in addition to hæmatoma even in the absence of any external wound Paralysis of abductor type affecting both vocal cords is a rare, but serious possibility Fixation of the crico arytenoid joints is a further complication that may arise The combined effects of injury may be followed by permanent stenosis due either to organization of effused blood and scarring at the level of the cricoid cartilage or to cohesion of the vocal cords with partial or complete obstruction of the glottis

When the active phase has subsided the correct treatment in a severe case is splitting the thyroid or cricoid cartilages followed by removal of obstructing scar tissue and the insertion of a rubber tube covered with a skin graft The tube is kept in place by means of a silver wire passed through the thyroid cartilage and cut off short beneath the skin (see Fig 790 p 813)

The character and degree of injury determines the length of sojourn of the tube which may have to be retained for a period varying from twelve days to six months Removal is effected by traction through a laryngoscope the pull must be sufficient to bring the wire out with the tube

OBSTRUCTION BY FOREIGN BODIES

Extraneous débris entering by the mouth may lodge above or in the laryngeal aperture and cause respiratory embarrassment

If the obstructing object is large and impacted in the hypopharynx death may occur before effective assistance can be given

If the necessary instruments are available in the form of a direct laryngo scope and grasping forceps the correct procedure is removal under vision. But as this equipment is unlikely to be at hand an alternative must be suggested

Attempts to remove the obstructing object blindly either with the finger or with forceps will in all probability fail the attempt may only drive the foreign body more firmly into the larynx It is advisable in such desperate circumstances to make an incision through the crico thyroid membrane The gap is readily felt with a finger and can be incised with any scalpel or even a penknife A transverse cut is first made and is then opened by the handle of the knife inserted through the opening and turned sideways

The patient s life may thus be saved and respiration may be restored by maintaining the patency of the slit until the foreign body can be removed If available a laryngostomy cannula is inserted it should remain *in situ* for no more than a few hours If the laryngeal airway has not then been restored tracheostomy should be performed

Instances have been quoted of asphyxia due to the falling back of the tongue over the laryngeal aperture in an unconscious man, the same accident may happen if the mandible is fractured on both sides Obstruction will be relieved if the tongue be pulled forward and kept in this position, if necessary by traction on a stitch passed through it

Simple fracture—Fracture of the thyroid cartilage is of little account unless accompanied by much local extravasation of blood Similar injury of the cricoid is, however, of serious moment, owing to the consequent obstruction to respiration Tracheostomy may be necessary as a temporary measure

In all probability the airway will be restored spontaneously, but the possibility of stenosis may call for an operation similar to that described above

PENETRATING WOUNDS

Types of injury—The epiglottis may be damaged or even removed altogether by gunshot wounds, the loss of this organ is of itself of no importance and no final ill-effects are felt The dangers are immediate and are due to the various factors outlined below

The thyroid cartilage is readily injured, but the damage would of itself be of no great significance were it not for associated injuries

The cricoid cartilage, on the other hand, is of great importance in maintaining patency of the airway, direct injury causes collapse and narrowing of the airway, while spread of inflammation leads to obstruction to respiration Effects on the joints of the arytenoid cartilages have already been referred to as producing fixation of the vocal cords Injury to the margins of the glottis may produce adhesions between the two sides or, alternatively, complete stenosis, collapse of the cartilaginous framework helps in the production of narrowing

The hyoid bone may be injured by the same projectile that hit the larynx

General effects—Penetrating wounds of the larynx are dangerous, not only because of the respiratory obstruction caused by rapid swelling of the soft tissue, but also because of the possibility of perichondritis and other complications The immediate mortality is high and therefore few cases are seen in hospital, those that survive the first few hours are a cause of anxiety The causes of death are hæmorrhage, suffocation and, later, cellulitis of the neck and septic infection of the lungs

Wounds of the larynx are less commonly seen than are those of the jaws and pharynx, because of their greater mortality Penetrating anteroposterior wounds seldom allow the patient to survive, owing to injury to the spine (Fig 795) Oblique wounds involve the great vessels of the neck and are therefore rarely seen Transverse wounds of through-and-through type are more frequent and are sometimes accompanied by very little constitutional disturbance

It is extraordinary to observe the non-lethal penetrating powers of a bullet travelling straight, at the beginning of the flight, however, or if diverted or ricochetting, the effects are more disruptive It would appear that the missile is preceded by a cap of compressed air which splits the tissues in its passage through fascial planes

In the last war wounds of the larynx caused by bullets were more frequently met with than were those due to fragments of shell, probably because the latter cause rapid death

OBSTRUCTION TO RESPIRATION—Penetrating wounds may produce a fistula into the larynx and also œdema which rapidly causes swelling sufficient to obstruct the airway. The tissues are lax except over the vocal cords themselves; the latter are covered by squamous epithelium, and luckily there is less swelling in this narrow region than elsewhere.

Obstruction may be due in part to submucous hæmorrhage. Fracture and indriving of the thyroid cartilage, or fracture and displacement of the cricoid, together with swelling of the perichondrium, may embarrass respiration.

The later appearance of inflammatory swelling, sometimes due to perichondritis, adds further to the difficulty in breathing.

Injury to the recurrent laryngeal or possibly the vagus nerve, either by direct violence or the pressure of a hæmatoma, may paralyse one or rarely both vocal cords. In the former case respiration is not materially impeded, but in the latter event dyspnœa is extremely severe.

Associated wounds of the pharynx may add to the dangers by the descent of blood and obstruction by clots. The impaction of a foreign body or of débris is a further possible cause of blockage.

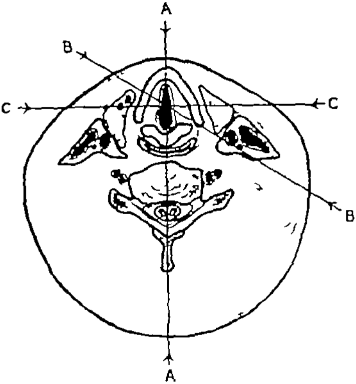

FIG. 705

Transverse section of the neck at the level of the vocal cords to illustrate the course of penetrating missiles.

A shows the course of a bullet or piece of shell hitting the larynx and also wounding the vertebral column or vice versa. A missile diverging considerably from the true anteroposterior plane may still hit the spine or injure the vertebral vessel. The axis B-B illustrates how an obliquely diverted wound may involve the contents of the carotid sheath. Here again, there may be considerable divergence from the line depicted. The plane C-C offers the only route of penetration by a fast moving object without probable fatal results.

(Adapted from Cunningham, Text Book of Anatomy.)

HÆMORRHAGE from divided neighbouring vessels may be severe and may be accompanied by hæmoptysis and cough. Recurrent hæmorrhages are to be feared. It is possible that the external carotid artery or the inferior thyroid may have to be tied, or ligature of individual vessels may be required. Apart from the immediate effects of hæmorrhage and suffocation there are further dangers incidental to sepsis.

PERICHONDRITIS follows infection in this region in a majority of cases and is much to be feared; the inflammatory process spreads rapidly and may affect the covering of the thyroid, cricoid and arytenoid cartilages as well as the joints between the two latter. The whole larynx appears swollen

enlarged and tender, and the outlines of the cartilages are obscured. Fluctuation may appear. Ulceration may later appear in exposed areas, and necrosis is also a possibility, advancing to a stage where there is shedding of considerable portions of cartilage. The combined processes can lead to almost complete destruction of the thyroid or cricoid cartilages. If the patient survives, the resultant scarring and contraction cause stenosis of varying degree.

The method of dealing with this complication is considered later.

Surgical emphysema is another effect of penetrating wounds, due to the entrance of air into the connective tissue planes. This complication is likely to occur when there is unrelieved laryngeal obstruction; forced inspirations suck air into the fascial layers, with distension of the tissues, sometimes to an alarming extent. The presence of air is recognized by crepitation; the diagnosis between simple surgical emphysema and gas gangrene may present temporary difficulties.

If air enters the mediastinum the dangers are considerably increased by respiratory embarrassment. No direct active treatment is required for surgical emphysema, but respiratory obstruction must immediately be relieved by tracheostomy. The air is absorbed in a few days with no ultimate ill-effects.

Parapharyngeal infection.—The sepsis incidental to some wounds of the larynx gives rise to various troubles other than those caused by perichondritis. Infection alongside the larynx may lead to the formation of an abscess in the parapharyngeal space, or at the side of the larynx, trachea or œsophagus. Swelling appears, sometimes due in part to surgical emphysema; it may assume a tense character and must be opened widely by a vertical incision over the sternal insertion of the sternomastoid muscle. Tracheostomy may be necessary. Failure to procure early and free drainage predisposes to *mediastinitis, a contingency with uniformly bad results.*

Difficulty in swallowing occurs with wounds in this region, if swelling of the aryepiglottic folds is marked, or if there is loss of tissue on the posterior surface of the larynx. It may also be due to associated injury of the pharynx; but even so, the symptom may be entirely absent even with extensive wounds. An œsophageal feeding tube will, on occasion, be required. Injury to the posterior wall of the larynx may produce a fistula into the œsophagus, with escape of fluids into the trachea.

Changes of voice may be absent or slight. When present, they are due to swelling of the vocal cords, ventricular bands or aryepiglottic folds, or to obstruction of the trachea. Aphonia or dysphonia appear also if perichondritis with deficient movement of the arytenoid cartilages is present.

Changes of voice can be caused also by fixation of the crico-arytenoid joints, due to inflammatory processes associated with perichondritis. But in some cases of marked fixation the voice may be good. The appearances vary in the different forms of immobility of the vocal cords. Cases of paralysis, due to interference with the nerve supply, show falling forward of the aryepiglottic fold, with incurving of the cartilage of Wrisberg and shortening of the affected vocal cord. Fixation of the crico-arytenoid joint, caused by injury or arthritis, does not necessarily produce these alterations.

of position as noted when the healthy side is compared with the unaffected half of the larynx

Hoarseness or aphonia may be due to interference with the nerve supply of the intrinsic muscles of the larynx this can come about in one of two ways The more common cause is damage to one or other—or possibly both—recurrent laryngeal nerves The second and rarer mode of damage is interference with the vagus nerve The nerve supply may be injured by shock by division of the nerve by the pressure of a hæmatoma or by involvement in scar tissue

If only one cord is paralysed the symptoms may be slight and the change of voice although apparent not marked The effects are immediate and recovery is rare

If both cords are affected there will probably be dyspnœa of dangerous character in addition to changes of voice

Inspection of the larynx shows deficient abduction in early and slight cases and complete paralysis with later and more severe types of injury this is in accord with general experience of other types of laryngeal paralysis

Treatment directed expressly to relieve the damage is impracticable and unnecessary in unilateral cases but is necessary if there is abductor paralysis of both cords In this type of injury dyspnœa of extreme degree necessitates tracheostomy and this will almost certainly be permanent

Injuries of the laryngeal nerves are sometimes associated with damage to various other nerves including the sympathetic glossopharyngeal spinal accessory and hypoglossal and the brachial plexus

Respiratory infections—Septic bronchitis and broncho-pneumonia are dangers to be apprehended, particularly in the first few days succeeding the injury Avoidance of these dangerous complications necessitates early and free drainage of septic areas and the relief of laryngeal obstruction If descending infection occurs great help is obtained by the frequent use of a suction apparatus to remove septic secretions This is only possible when there is an available wound or when tracheostomy has been performed A fine rubber catheter is passed through the metal tube

Treatment—The immediate aim is to save the life of the patient This necessitates control of hæmorrhage avoidance of entrance of blood into the trachea and the prevention of obstruction to respiration

It is difficult to carry out more than simple measures in the regimental or first aid post it is therefore necessary to transport the casualty to better equipped surroundings at an early opportunity

The patient should be sat up as in this position he will more readily cough up blood that trickles into the trachea

It is wise to avoid the use of morphia owing to its depressing effect on the cough reflex and respiratory centre the patient s life may depend on his ability to protect his airway by coughing

For similar reasons atropine is to be avoided as a routine because of its effect in diminishing the supply of mucus, without which ciliary action is incapable of ejecting bacteria from the bronchi and trachea

Obvious bleeding points should be controlled if necessary by application of artery forceps if this is not practicable external pressure must be relied on If however the compression has the effect of increasing the amount of

enlarged and tender, and the outlines of the cartilages are obscured Fluctuation may appear Ulceration may later appear in exposed areas, and necrosis is also a possibility, advancing to a stage where there is shedding of considerable portions of cartilage The combined processes can lead to almost complete destruction of the thyroid or cricoid cartilages If the patient survives, the resultant scarring and contraction cause stenosis of varying degree

The method of dealing with this complication is considered later

SURGICAL EMPHYSEMA is another effect of penetrating wounds, due to the entrance of air into the connective tissue planes This complication is likely to occur when there is unrelieved laryngeal obstruction, forced inspirations suck air into the fascial layers, with distension of the tissues, sometimes to an alarming extent The presence of air is recognized by crepitation, the diagnosis between simple surgical emphysema and gas gangrene may present temporary difficulties

If air enters the mediastinum the dangers are considerably increased by respiratory embarrassment No direct active treatment is required for surgical emphysema, but respiratory obstruction must immediately be relieved by tracheostomy The air is absorbed in a few days with no ultimate ill-effects

PARAPHARYNGEAL INFECTION—The sepsis incidental to some wounds of the larynx gives rise to various troubles other than those caused by perichondritis Infection alongside the larynx may lead to the formation of an abscess in the parapharyngeal space, or at the side of the larynx, trachea or œsophagus Swelling appears, sometimes due in part to surgical emphysema, it may assume a tense character and must be opened widely by a vertical incision over the sternal insertion of the sternomastoid muscle Tracheostomy may be necessary Failure to procure early and free drainage predisposes to mediastinitis, a contingency with uniformly bad results

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of detached and infected pieces of cartilage and by the excision of lacerated or infected skin edges

Foreign bodies must be taken out as soon as convenient after radiographic examination The latter should be performed early and repeated if suspicion of sequestration arises

As most dangerous infections in this region are streptococcal or pneumococcal it is wise to give a course of sulphonamide therapy for three or four days The local application of the powdered drug is of service

If cellulitis occurs there must be free incision over the affected areas If signs of parapharyngeal abscess appear as evidenced by swelling at the side of the larynx or trachea probably associated with crepitation due to surgical emphysema free drainage must be provided

A vertical incision is made in the line of the sternal attachment of the sternomastoid muscle extending from the top of the thyroid cartilage to the sternum The carotid sheath is displaced outwards and a finger inserted between it and the larynx The inferior thyroid artery and veins must be tied as they cross the gap so made

The wound is left freely open the skin edges are best kept apart by the insertion of folded oiled silk packed from within with gauze impregnated with iodoform or sulphonamide powder

FIG 796

Operative treatment of laryngeal stenosis A rubber tube covered with a skin graft, has been inserted into the larynx and trachea.

Sequelæ—If the patient survives the dangers of hæmorrhage asphyxia perichondritis and infection of the lungs he may still have subsequent disability from stenosis of the larynx Obstruction may be caused by adhesion of the vocal cords to one another by falling in of the soft tissues consequent on the destruction of the cartilaginous framework of the larynx or trachea by narrowing at the level of the cricoid cartilage owing to the formation of organized granulations or by fixation of the crico arytenoid joints

Treatment has already been referred to The thyroid, cricoid or tracheal cartilages are split in the mid line according to the site of obstruction tracheostomy is a necessary preliminary All signs of activity must be allowed to disappear before operation is contemplated.

Scar tissue is excised and the lumen of the airway is restored. Adhesions are freed according to their site

If the cartilaginous framework has been severely damaged, it may be possible to replace it by insertion of cartilaginous or bony grafts; this step is, however seldom desirable or necessary

As already described a skin graft is inserted into the restored lumen and is maintained in place by a rubber tube (Fig 796) (see p 807) If the rigid structures have been severely damaged it is desirable to leave the tube in position for two months to prevent contraction subsequent maintenance of the lumen can, if necessary be effected by an upward metallic extension attached to the tracheostomy tube If, however the thyroid and cricoid cartilages are intact the rubber tube may be removed after two or three weeks The manœuvre is simple and consists in exposing the larynx

inhaled blood, it must then be decided to allow free external escape, for fear of asphyxiating the patient

During transportation it is best to maintain the sitting position for the reasons already given The patient may be allowed to whisper if he so desires

CONTROL OF HÆMORRHAGE, whether primary, reactionary or secondary, is attained by the ligation of divided vessels after wide exposure, with extensive wounds it is advisable to tie the external carotid artery and not its individual branches Bleeding may be controlled by pressure and plugging in some cases, but ligation of the vessels is preferable Pressure must not be so powerful as to obstruct the airway Downward passage of blood may cause obstruction of the trachea and bronchi and may also lead to infection of the lungs, the latter possibility is greater if infected clots enter the lungs

If a suction pump is available, its use will be of great benefit in dealing with these complications

A soft rubber catheter is passed through the wound or down the tracheostomy cannula to remove the blood and secretions

RELIEF OF RESPIRATORY OBSTRUCTION—If there is severe dyspnœa, and if there is a wide enough external fistula, it is permissible to insert a cannula as a temporary measure If the wound is not of suitable size and position, it is justifiable, in emergency, to make an incision through the crico-thyroid membrane in order to introduce a laryngostomy tube But in neither case must these measures be considered as more than temporary means of relief, because the retention of a tube in contact with the laryngeal cartilages for more than a few hours will cause perichondritis

As soon as possible, tracheostomy should be performed under local anæsthesia The trachea is opened, preferably at the level of its third or fourth ring, the first ring must never be cut and the second is best left untouched A detail of technique of some importance is the making of a window in the trachea, sufficiently large to admit the cannula, while preventing passage of air past its margins This modification prevents sloughing of cartilage, which may occur if only a slit is made It permits free respiration if the cannula becomes dislodged and has to be removed temporarily It also enables easy replacement of the tube

Tracheostomy is required in a considerable proportion of laryngeal wounds It should not be delayed if marked stridor is present while the patient is awake, avoidance of the operation has the danger of predisposing to surgical emphysema and respiratory infections

Dangers should not be great if the operation is performed satisfactorily under local anæsthesia and if after-treatment and nursing are efficient Septic secretions must be prevented from trickling down the trachea by the provision of free drainage, by the use of suction when available and by the frequent renewal of dry dressings to act as absorbents If by mischance or misjudgment the cannula has been introduced so high in the trachea as to cause irritation of the cricoid cartilage, the first necessity, after discovery of the mistake, is to perform a second operation and to replace the tube at a lower level

LOCAL SEPSIS is treated by the provision of free drainage, by the removal

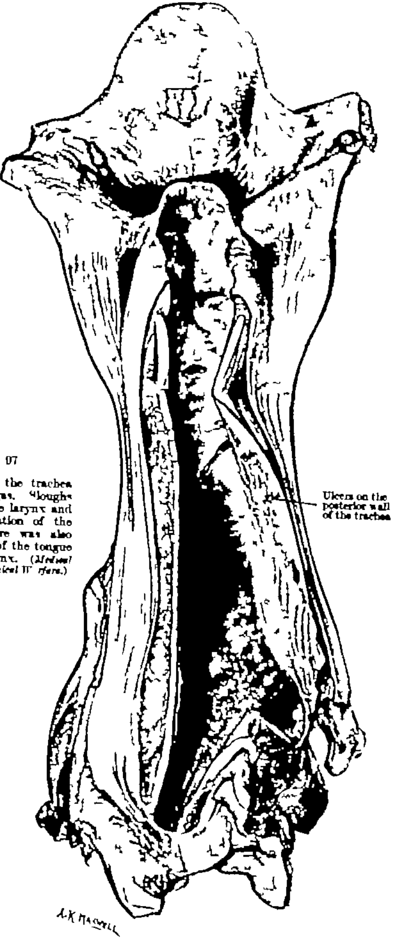

FIG. 97

Ulceration of the trachea by mustard gas. Sloughs are seen in the larynx and at the bifurcation of the trachea. There was also inflammation of the tongue and the pharynx. (*Medical Manual of Chemical Warfare.*)

through a direct laryngoscope and pulling the tube and silver wire out with strong forceps, the wire must be sufficiently flexible to withdraw without undue difficulty

A fistula between the larynx and pharynx or œsophagus will require repair This is effected by opening the larynx and incising the mucosa at either edge of the fistula

The cut margins are turned inwards and united, thus leaving a raw surface on the laryngeal or tracheal aspect To this area a skin graft on a rubber tube is applied, as already described, in some cases a skin flap is required to close the defect The three conditions mentioned, cohesion of the vocal cords, stenosis at the level of the cricoid cartilage and laryngo œsophageal fistula, were present in the patient whose radiograph is illustrated (see Fig 796) Treatment was carried out on the lines detailed above, with restoration of normal respiration, phonation and deglutition

A fistula between the larynx and the exterior is dealt with by splitting the margins of the adherent skin and mucosa and closing the gap in layers by stitches, or, in extensive defects, by the use of skin flaps

If the deficiency is wide it is necessary first to turn over a flap of skin to face inwards and to unite it to the split edges of the wound A second flap, derived from the region above or below the defect, or slid in from one side, is then used to cover the raw surface

WOUNDS OF THE TRACHEA

Injuries of the trachea are of slightly less importance than wounds of the larynx if situated in the extrathoracic portion One reason is the greater calibre of the trachea The glottis is the narrowest part of the airway and is therefore more liable to obstruction, whereas the trachea possesses a considerable reserve of cross-sectional area beyond the usual necessities of respiration Secondly, there is less liability to perichondritis of the tracheal rings as compared with the cartilages of the larynx

Patients with wounds in this region are seldom seen alive, owing to the proximity of vital structures in the neck, including the spinal cord and great vessels

Damage to the intrathoracic portion is almost always associated with injury to the pleura and lungs, while the proximity of large vessels still further adds to the gravity of such a wound It is possible, however, for the patient to survive, at least temporarily, after sustaining a wound of such a type

The œsophagus may be damaged by the missile, with the further production of an œsophago-tracheal fistula, survival is then unlikely

Penetrating wounds of the extrathoracic part do not require treatment differing from that outlined in dealing with the larynx Descent of blood and of septic secretions are the chief dangers, aspiration with a catheter passed through the wound is desirable if a suction pump is available

It is possible that stenosis may supervene in cases that recover, operation for the restoration of a sufficiently wide lumen is then required, with insertion of a skin graft held in place by a rubber tube

In some cases a plastic operation is preferable, skin flaps being turned in and subsequently united to restore the airway

THE EFFECTS OF GAS ON THE UPPER AIR PASSAGES

Certain inhaled gases cause irritation of the mucous membranes of the nose, pharynx and larynx The effects are, however, not so marked as

It is advised to irrigate the nose and nasopharynx with a solution of sodium bicarbonate

Prevention is effected by the wearing of a respirator before the vapour can be inhaled The delayed action of mustard gas presents difficulties Indicators showing a change of colour when the gas is about are useful the smell of the gas resembles garlic and may be a guide to its detection

Patients with tracheostomy require a special respirator of the hooded type

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in the bronchioles and alveoli A short account will be given of the various irritants, classified according to the regions which they affect

Lachrymators or tear gases irritate the eyes and may in high concentrations affect the lungs

Nasal irritants or nose gases are mostly arsenical compounds, they cause intense pain in the nose, sinuses and chest, associated with lachrymation, fullness in the head, sneezing, salivation and vomiting The symptoms subside one hour after removal from the gassed area The effects are upsetting rather than dangerous.

Lung irritants or choking gases include chlorine, chloropicrin and phosgene They affect both the lower as well as the upper air passages, death may occur from pulmonary œdema Early symptoms include catching of the breath, with choking and coughing, followed by asphyxia and cyanosis

Of these gases PHOSGENE is not of great importance in the present connection, as its effects are felt mainly in the lungs, where acute inflammatory œdema is produced There may be desquamation of the mucosa of the trachea, but no marked effects in the nose or larynx.

Neither symptoms nor signs are marked in the upper air passages

Vesicants or blistering gases include mustard gas and lewisite The results of exposure show themselves as acute conjunctivitis and inflammation of the mucous membrane of the respiratory tract Shock, followed by septic bronchitis or broncho-pneumonia, may cause death (Fig 797)

MUSTARD GAS is peculiar, having a delayed action, its effects being felt only after a lapse of two to six hours There is marked local reaction, with rhinitis, conjunctivitis and possibly necrosis or desquamation of the tracheal mucosa, where sloughing may take place

Bacterial infection may follow and cause secondary septic broncho-pneumonia, death results from the latter complication and not from the primary effects of the gas Of minor signs, laryngitis is to be mentioned, as well as rhinitis and conjunctivitis, the sense of smell is soon dulled Hoarseness and aphonia are frequent symptoms There may be œdema and sloughing of the vocal cords after exposure to high concentrations of the gas, with dry, irritating cough as a result of the effects on the trachea The pharynx as far as the crico-pharyngeal folds may show marked reactionary changes, the œsophagus is unaffected. Involvement of the lower respiratory passages produces generalized œdema with disruptive emphysema, profuse mucopurulent sputum, with rising temperature and pulse, are advancing signs The patient dies of asphyxia For the larynx an oily spray of liquid paraffin is recommended, together with steam inhalations of menthol and benzoin Irrigation of the nasopharynx with sodium bicarbonate is said to be of use If the patient survives, cough may persist, aphonia may be prolonged, but if so it is probably functional in type There should be practically no permanent after-effects

LEWISITE resembles mustard gas but is quicker in action and also has a severe toxic effect by local absorption The nasopharynx is affected in a very few minutes after exposure

The gas is very irritating to the nose and causes *sneezing, together with* lachrymation

CHAPTER LXXII

WOUNDS OF THE ORBIT

WOUNDS of the orbit are generally due to direct violence Very rarely are they due to fracture of the skull extending into the orbit Even in cases of the gravest gunshot wounds of the cranial vault there is no evidence of orbital fracture (Lagrange) However it must be noted that radiographs often fail to show fractures of the orbital walls

On account of their high velocity bullets inflict the most severe injuries Both orbits may be traversed (Fig 708) and in a number of cases considerable

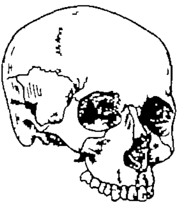

FIG 708

Right antero-lateral view of cranium, showing perforating gunshot wound involving both orbits. The arrow indicates direction taken by missile (*British Journal of Surgery*)

FIG 709

Antero-lateral view of cranium, showing extensive comminution of right orbit. The missile (a fragment of shell) can be seen at the superior medial angle of right orbit. (*British Journal of Surgery*)

damage is done to intracranial structures and the accessory nasal air sinuses Among soldiers who survive bullet wounds of the orbit it is remarkable that the course of the missile is so frequently oblique (Fig 709) the direction being very variable and involving the skull brain, nose face jaws and neck, thus adding considerably to the associated complications The relative extent and severity of bullet injuries is due to the tearing ripping and bursting effect produced in traversing tissues of varying density Several machine gun bullets may become lodged in an orbit causing a severe degree of exophthalmos In some cases the orbital walls are driven in but not perforated by the fragment but the concussion effect on the eye and orbital contents is considerable The commonest marginal injuries are depressed and comminuted fractures of the malar bone and the supra-orbital margin associated with large lacerations of the soft parts of the brow eyelids nose

and proliferating choroido retinitis (see chapter Non perforating Injuries of the Eyeball)

Avulsion of the optic nerve is characterized ophthalmoscopically by deep excavation at the site of the optic disc attenuation of the branches of the central retinal vessels peripapillary white exudate fibrous tissue and hæmorrhages Later the cavity at the optic disc becomes filled in with cicatricial tissue The optic nerve may be torn across between the globe and the optic foramen In some instances there may be characteristic ophthalmoscopic evidence suggesting a site of injury anterior to the entry of the central retinal vessels and therefore implicating these in the wound or behind this point leaving the vessels in some instances undamaged A tear in the optic foramen or optic canal is followed by ophthalmoscopic signs of optic atrophy obvious about three weeks after the wound

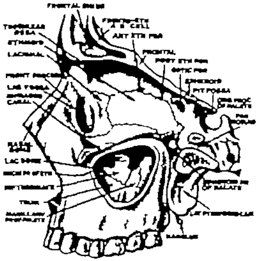

Fig 801
The medial wall of the orbit. (*After Wolff*)

Hæmorrhage into the optic nerve sheaths and inside the nerve may follow direct injury or severe concussion from a bursting shell In a few hours there is œdema of the optic disc and macula and peripapillary minute flame-shaped hæmorrhages The retinal arteries are reduced in calibre and the veins congested. Compression of the papillo-macular bundle causes a central scotoma and there is also some peripheral contraction of the visual field. In some cases hæmorrhages extend from the optic disc into the retina and vitreous Choroidal hæmorrhages and lesions at the posterior pole are sometimes associated with subdural and intraneural hæmorrhages of the optic nerve In severe cases there is at first complete loss of vision (no perception of light) followed by some recovery but rarely is this complete A residual sign of subdural and intraneural hæmorrhage is the presence of fine reddish brown pigment granules thought to be hæmatogenous around the optic disc and at the macula

Lagrange has reported a case of bilateral retrobulbar optic neuritis which he attributed to direct spread of inflammation from infected uveal and scleral remnants in the stump of a shattered eye removal of which was followed by subsidence of the optic neuritis and visual recovery in the uninjured eye

Muscles—The action of the extra-ocular muscles is often impaired in wounds of the orbit owing to concussion effects hæmorrhage tears either through the tendinous insertion or the muscle belly avulsion from the site of origin at the apex of the orbit (from the floor in the case of the inferior oblique) and damage to nerve supply The pulley of the superior oblique is dislocated in fractures involving the supero medial quadrant of the orbit Wounds in the upper part of the orbit and fractures of its upper wall may also involve the levator palpebræ superioris and superior rectus muscles the frontal lachrymal trochlear and upper division of the oculomotor nerves

and face together with loss of the eye A violent fall on the orbital margin following an explosion (" blown up ") may lead to partial or complete optic atrophy on the same side as a result of a fracture or hæmorrhage, damaging the optic nerve at the optic foramen or in the optic canal Bayonet thrusts in the orbit are a rarity

EFFECTS OF ORBITAL WOUNDS

The effects of orbital wounds depend upon the size, shape, number, velocity and course of the missiles Figs 800 and 801 illustrate the more important anatomical relations of the orbit and some of its contents

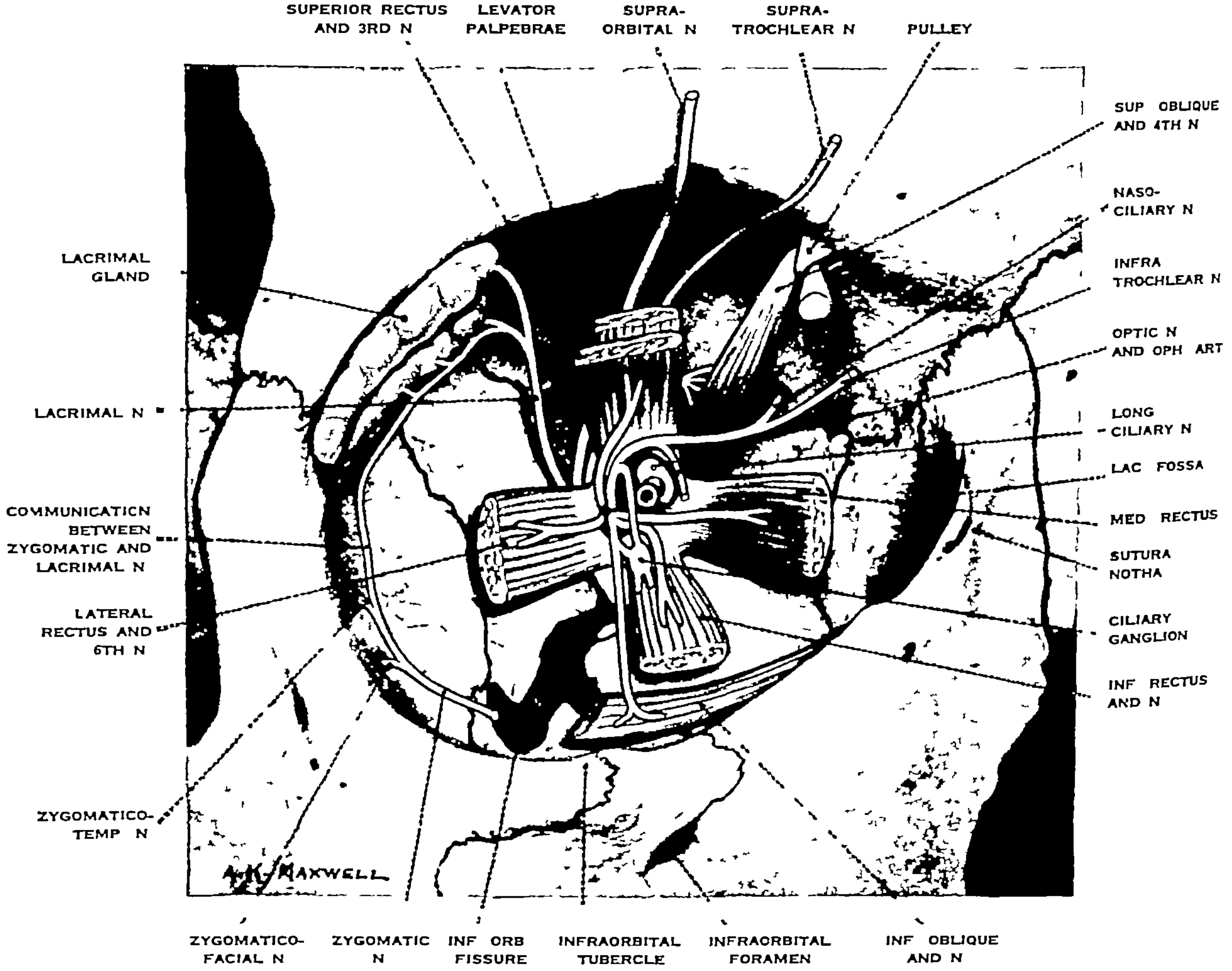

FIG 800

Dissection to show orbital nerves from in front (*" Wolff's Anatomy of the Eye and Orbit," Lewis*)

The eye and optic nerve—In some cases the eye escapes damage, in others it is completely disorganized and all that remains is a painful inflamed stump composed of fragments of sclera and uveal tract attached to the optic nerve sunk deep into the orbit or even displaced into the antrum Concussion may cause splits and tears in the intra-ocular membranes traumatic cataract, retinal detachment, commotio retinæ, retinitis proliferans

and proliferating choroido retinitis (see chapter Non perforating Injuries of the Eyeball)

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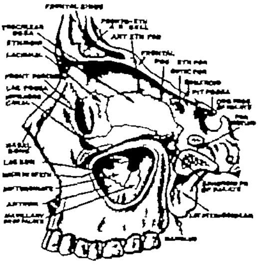

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Wounds in the lower part of the orbit damage the inferior oblique and inferior rectus muscles, the external rectus is commonly injured when the malar bone and lateral wall are involved, and the internal rectus has been torn clean away from its insertion in wounds of the medial wall

The signs of muscle injury are absence or impairment of its action, diplopia and, if the injury is in front of the equator, local tenderness Diplopia is compensated in some measure by a characteristic turn or inclination of the head towards the direction in which the injured muscle acts In severe cases total ophthalmoplegia and luxatio bulbi may be evident The sphincter pupillæ muscle may be involved in radial splits in the pupil margin, also iridodialysis and traumatic mydriasis may be the result of concussion Very rarely is there paralysis of accommodation

The sympathetic nerve has been divided in the neck and its perivascular fibres at the apex of the orbit by bullet wounds traversing the neck, face, orbit and skull Enophthalmos, ptosis, constriction of the pupil and other characteristic defects in sympathetic nerve supply have been noted Some return of function has been observed four months after the injury

Blood vessels—Severance of important blood vessels at the back of the orbit produces rapidly increasing exophthalmos The eye is displaced directly forwards, there is subconjunctival ecchymosis and infiltration of blood into the lids and adjacent soft tissues of the face In severe cases luxatio bulbi occurs, but later the eye may resume its normal position but vision be lost (For arterio-venous aneurysm see Chapter XXVIII)

Lachrymal passages—Epiphora may be caused by eversion of the lower punctum associated with traumatic ectropion of the lower lid, occlusion of the lower punctum and canaliculus from fibrosis of a healed lacerated wound and fibrous or osseous obstruction in the lachrymal sac and naso-lachrymal duct the sequel of a perforating wound and fracture

COMPLICATIONS OF ORBITAL INJURIES

The immediate complications of orbital injuries are those due to the damage of its important structures and are described briefly above The following are some of the commoner complications that may arise soon after the injury or at a more remote date

Surgical emphysema is more commonly associated with wounds of the medial wall of the orbit, but it may also occur when an orbital fracture extends into any of the accessory nasal air sinuses that retain a patent communication with the nose

Infection—Infection with pyogenic organisms is common when the accessory nasal sinuses are involved and particularly when fragments of missiles are retained in their cavities Infection spreads from the nose to the cellular tissues of the orbit and leads to orbital cellulitis and abscess formation in the muscle cone and elsewhere in the orbit Cavernous sinus thrombosis, extradural abscess, acute meningitis and cerebral abscess are infective complications associated with orbital wounds

Lagrange reports the case of a French soldier whose lids were adherent after an orbital wound This patient gave no symptoms or signs of meningeal or cerebral complications, and radiographs

did not reveal a fracture of the orbit. Through the closed lids a round swelling in the orbit about the size of the eye was palpated. The adherent lid margin was divided with scissors and at the same time opened an infected meningo-encephalocele After this operation there occurred spreading meningitis and encephalitis and the patient died.

The retention of infected remnants of uveal tract in the stump of a disorganized eye may endanger the other eye with sympathetic ophthalmitis Fibrosis after subsidence of orbital cellulitis is said to cause enophthalmos and impairment of all ocular movements Gas gangrene of the orbit is quite rare

Nerves—Damage to the branches of the ophthalmic division of the trigeminal nerve may result in trophic changes in the cornea and lead to neuroparalytic keratitis Division of the sympathetic nerve fibres has been blamed for a trophic disorder characterized by atrophy of the orbital fat followed by enophthalmos impaired mobility of the eye corneal ulceration, keratitis entropion and trichiasis owing to the absence of mechanical support to the lids Involvement of the infra-orbital nerve in scar tissue and callus has been the cause of blepharospasm and photophobia which have disappeared on freeing the nerve In fractures of the roof of the orbit hernia cerebri may be a troublesome complication.

Exposure ulceration of the cornea—A degree of exophthalmos which does not allow comfortable closure of the lids over the whole cornea may endanger the vitality of this structure from drying loss of epithelium ulceration and infection Hypopyon and panophthalmitis are serious complications the latter being fatal to the eye Severe orbital hæmorrhage relatively large or multiple orbital foreign bodies and cellulitis are the usual causes of severe exophthalmos

INVESTIGATION OF AN ORBITAL WOUND

Clinical—The *inspection* should be made from the front the side and by standing behind the patient and looking over the frontal bone supra-orbital margin and nose from above Disparity in size of the orbits asymmetry in shape depression of the margins differences in the level of the two eyes and other associated facial defects should be noted A careful survey of the scalp should be made for sometimes minute shell fragments enter the occipital region and pass forwards through the brain to become lodged in an orbit The nose should be examined externally and through a speculum for evidence of fracture of the medial wall of the orbit or an intra nasal foreign body The frontal sinuses and antra should be transilluminated for the presence of a large foreign body pus and blood The mouth should be looked at for any deformity of the hard palate and maxillæ The neck may be the site of an entry wound of a bullet which has divided the cervical sympathetic and may have traversed the mouth and face to end in an orbit Defects deformities discoloration and loss of mobility of the lids are noted Desmarres retractor (Fig 802) is inserted and the upper lids gently separated from the lower without pressure on the globe

FULL SIZE

Fig 802 Desmarres retractor

An external examination of the eye is made supplemented by

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skin flap including the buccal mucous membrane inlay is fashioned so that it may be drawn over the fistula and secured by mattress sutures The stent is removed and the buccal mucosa trimmed in order to fit the aperture in the sinus wall and any defect left by sliding the skin graft is repaired by the Thiersch method Four weeks later a slice of cartilage is inserted between the skin and the mucous membrane graft so as to build up a secure wall and fill in any depression that may exist Cartilage should not lie directly in contact with an air sinus it becomes infected then extruded In this as in plastic surgery of the eye nose and mouth it is essential to construct first a suitable lining then add the overlying skin and supporting tissues Cartilage and bone grafts should always be covered by fascia If the skin is sutured directly over such grafts they may become extruded

Exploration of the orbit—Foreign bodies situated in the orbital tissues within 2 cm of the orbital margin may be extracted through an appropriate incision through the lids but when placed behind this level the retro-ocular contents of the orbit must be exposed by means of a Krönlein s operation (Fig 803) In the Krönlein operation it is often necessary to divide the external rectus muscle and this should be done if possible between the equator and its insertion in order to avoid damage to its nerve supply and at the end of operation the external rectus muscle belly must be kept clear of the resected bone of the outer orbital wall when it is replaced, otherwise adhesions may form and also be a cause of impairment in its action Large foreign bodies will be evident and must be removed with careful attention to adjacent structures and with the avoidance of damage to the optic nerve and intra-orbital nerves and vessels Small foreign bodies are difficult to locate Gentle exploration with the gloved forefinger may detect the site or failing this a long terminal of an electromagnet may be introduced and the extraction of the foreign body assisted by separating any adherent tissues with a fine pair of blunt dissecting forceps The lower and outer angle of the orbit and the skin flap should be drained for forty-eight and twenty four hours respectively after Krönlein s operation It is a safe precaution to perform preliminary tarsorrhaphy before operation and to leave this for three or four weeks during the post-operative subsidence of exophthalmos

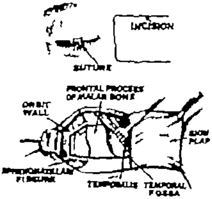

Fig 803
The Kronlein Operation

Tarsorrhaphy is also a safe preventive measure before operating on an orbital abscess particularly when this is associated with frontal sinusitis If a firm tarsorrhaphy has not been done the temporary post-operative orbital œdema may cause exposure ulceration and infection of the cornea with hypopyon and loss of the eye from panophthalmitis To avoid such ocular disasters in progressive or severe exophthalmos due to orbital wounds tarsorrhaphy is necessary If this is either mechanically impossible or the tarsorrhaphy breaks down temporary protection of the cornea must be

a more detailed inspection with the binocular corneal loupe The visual acuity is estimated and a rough visual field may be taken by the confrontation test or by projection of light A fundus examination is made if the transparency of the media permits this The ocular movements are tested and the remainder of the cranial nerves are investigated Some concussion injuries producing ocular and orbital damage also cause rupture of the tympanic membrane on one or both sides, followed by mucopurulent discharge from the external auditory meatus

Palpation elicits the nature of a depression, local tenderness, crepitus, osseous or due to surgical emphysema, pulsatile exophthalmos, the presence of foreign bodies, fluid It may also be used to determine roughly the intra-ocular pressure The intra-ocular pressure may be assessed more precisely by Schiötz's tonometer

The patency of the lachrymal passages is tested by dilatation of the lower punctum and gentle irrigation with sterile normal saline

X-ray examination will show marginal fracture defects of the orbit and the grosser fractures of its walls, but some losses of bony continuity in the walls are not evident in radiographs Foreign bodies are located by stereoscopic methods The introduction of lipiodol into the lachrymal passages is a necessary diagnostic procedure in some cases Localization of an orbital foreign body by passing a probe and taking radiographs during operation may be necessary

Pathological investigation—A smear should be made from discharge and a culture prepared

TREATMENT

First-aid treatment in the field consists of cleaning the orbital area and covering it with a dressing and treating the shock, which is often severe, especially if the globe is ruptured The wound should on no account be probed until a reliable X-ray has been taken and there are proper facilities for completing any necessary operative procedure Fine judgment is often required in order to assess the dangers either of leaving a foreign body *in situ*, or the advantages of its extraction and the prognosis of complications

In the case of compound (open) fractures early excision of the wound should be performed Bone splinters adherent to periosteum should be left, but if free they should be removed Fractures of the orbital wall are often more serious than those of the margin on account of the greater shock to the brain, and the difficulties in establishing drainage They are often concealed and not evident on X-ray examination Death from meningo-encephalitis between the third and sixth days occurs in some cases Small orbito-palpebral wounds should be regarded seriously An infected wound, intracranial symptoms, a rising temperature and headache indicate the need for exploration, cleansing of the track and adequate drainage Sulphonamide therapy is of great value

Hernia cerebri requires treatment by repeated lumbar puncture and aseptic protection A cerebral abscess will need exploration and drainage In the closure of an infected fistula of an accessory nasal air sinus it is essential to remove any foreign body which it may contain, to wash out the cavity, and a week or so later to bury beneath the adjacent skin a buccal mucous membrane graft over a stent In eight to ten days a suitable sliding

avoid this it may be necessary in some cases to perform a preliminary operation to mobilize the skin and to add a Wolfe or Ollier Thiersch graft to make up any deficiency

A depressed fracture of the malar bone may be corrected by splitting the anterior third or half of the temporal muscle and turning it downwards and forwards beneath a bridge of skin at the outer angle of the orbit and suturing it to the soft tissues over the depressed fracture A folded pad of fascia lata cut together with some fat from over the tensor fasciæ femoris is also satisfactory The fascia must be applied so that it lies outwards and the fat inwards If wasting of the fat occurs at a later date the depression may be filled in with a cartilage graft

Depressed fractures of the floor of the orbit cause enlargement of the orbit the eye is on a lower level than its fellow deformity of the cheek is evident and diplopia may be troublesome Sometimes elevation of the depressed fragments may be effected long after the accident but it is often impossible to reduce satisfactorily such fractures A wedge of costal cartilage of appropriate dimensions inserted into the floor of the orbit gives a good result Fractures of the medial wall may be reduced by intranasal manipulations and the retention of fragments maintained by wearing an intranasal device moulded from gutta percha In some cases it is necessary to explore the medial wall from the orbital aspect through a curved incision Lagrange recommends Krönlein s operation combined with this, so as to facilitate lateral displacement of the orbital contents but generally the exposure through a large incision around the medial side of the orbit is adequate

The lachrymal passages—Epiphora due to eversion of the lower punctum associated with traumatic cicatricial ectropion may be corrected by plastic repair of the ectropion Occlusion of the lower canaliculus from a tear and fibrosis may in some cases be corrected by a plastic procedure utilizing folds of adjacent conjunctiva but this is difficult and often unsatisfactory Fractures of the medial part of the orbit and nose may cause severance and occlusion of the naso-lachrymal duct by fragments of bone and later callus formation. In such cases dacryocystorhinostomy has to be considered.

Socket—Retention of a prosthesis is impossible in a socket that is too small and when the lower fornix is absent and the conjunctiva forms a sloping shelf downwards and forwards It is desirable to have an upper fornix in some measure but this need not be so deep as normally and is not so essential for the retention of an artificial eye as the lower fornix

An orbit that is too deep may be built up either by fat and fascia graft or an ovoid cartilage graft Fat is liable to shrink and may become diminished during a wasting illness and senility but cartilage maintains a constant contour Boldness is needed in the reconstruction of a contracted socket Mucous membrane is the best tissue with which to line it but it is difficult to obtain sufficiently large grafts of this tissue and so in the majority of cases a very thin Ollier Thiersch graft is used All adhesions fibrous tissue and conjunctiva are dissected away and the socket is rendered as large as possible to allow for future contraction. A mould of stent is inserted into the socket its centre is perforated with a glass rod and it is cooled *in situ* by dripping cold saline over it It is removed and evenly covered

effected by covering it completely with a conjunctival flap, irrigating with a continuous saline drip apparatus, instilling drops of ol. parolein at one-hourly intervals or inserting a contact glass.

Cellulitis of the orbit is best treated expectantly and by short-wave diathermy. If an abscess becomes localized it should be incised and drained.

Corneal ulceration requires curettage of the débris in the floor of the ulcer, carbolization, atropine and a pad and bandage; daily irrigations of the conjunctival sac, either with normal saline or an antiseptic such as hydrarg. oxycyanide (1: 10,000). If there is mucopurulent discharge, atropine ointment and the instillation of cod-liver oil drops are indicated.

Hypopyon (pus in the anterior chamber) may require evacuation by paracentesis. Destruction of the globe from panophthalmitis necessitates evisceration of its contents. In some cases it is advisable to excise the sclera as well, leaving only a narrow frill around the site of the optic disc so as to avoid opening the sheath of the optic nerve and infecting the meninges.

EXTRA-OCULAR MUSCLES

In cases where it is thought that a muscle has been severely torn or completely divided at its insertion or in an accessible part of the muscle belly, exploration is justifiable when adjacent orbital hæmorrhage has in a large measure subsided and before fibrosis and contraction have set in.

In some cases of dislocation of the pulley of the superior oblique an attempt may be made to restore the pulley to its proper site. If the bones of the supero-medial wall of the orbit are considerably displaced this may be impossible, and to correct the diplopia operations on the opponents of the superior oblique will have to be planned.

PLASTIC RECONSTRUCTION OF THE ORBIT

It is seldom that depressed fractures of the orbit can be satisfactorily reduced by an operation and traction applied to the fragments in an attempt to restore the normal contour. Impaction, comminution and involvement of one or more accessory air sinuses necessitates some other procedure to correct the deformity.

The limits of a depressed fracture of the supra-orbital margin may be measured by making a cast and shaping this so that its outer surface corresponds to the normal symmetry. A well-nourished flap of skin is carefully dissected off the bone over the depressed fracture and into the cavity is placed a cartilage graft cut from the 7th costal cartilage and shaped to the exact size and shape of the cast. The perichondral surface of the graft should be placed, if possible, in a position where a concavity is required, for this surface bends in such a manner. The cartilage is secured in position with slings of mattress catgut sutures, or the bone and cartilage may be dovetailed by fashioning small slots in the bone and corresponding flanges on the cartilage. Fascia is drawn together over the cartilage and the skin flap sutured so that the line of stitches does not lie over the graft. It is most important not to have the skin flap under tension, and in order to

avoid this it may be necessary in some cases to perform a preliminary operation to mobilize the skin and to add a Wolfe or Ollier Thiersch graft to make up any deficiency

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with an Ollier-Thiersch graft, the deep surface of which is placed outwards This is embedded in the socket, a tarsorrhaphy is performed and a firm elastic pressure dressing of tulle gras, saline gauze, oil silk, marine sponge and crêpe bandage is applied The stent is left in for two or more weeks, but it may be extruded before this After removal a glass shell is worn in the socket to prevent contraction until the full size prosthesis is retained

The lower fornix alone may be reconstructed in some degree by burying a mucous membrane graft between the lower margin of the orbit and the floor of the socket, and opening this later to remove the stent and suture the conjunctiva to the mucosa Another method is to incise and undermine an apron of conjunctiva from the floor to the lower tarsus and to swing this vertically downwards and secure it by mattress sutures to the periosteum of the orbital floor The raw surface left in the floor of the socket is covered with a mucous membrane graft

An **eyebrow** may be reconstructed by cutting a rectangular dermo-epidermic strip of appropriate length and about 7 mm wide with shelving sides from the margin of the hair-bearing area behind the mastoid process The dermal fat is excised until the roots of the hairs are showing, and the graft is fixed by sutures in a bed prepared for it by incising the skin over the superciliary ridge down to the periosteum It is important to mark the upper edge of the graft with a notch before its transposition so that the hairs may be directed downwards and backwards

INJURIES OF THE EYELIDS

Wounds and burns affecting the eyelids and conjunctiva are of great variety, and often call for considerable surgical ingenuity and judgment in assessing the amount to do at any one stage of their plastic repair, and the length of the necessary intervals between these operations

It is of immediate importance to ensure that the eye, if it is still present or there is a reasonable chance of its preservation, has adequate covering protection Exposure of the cornea will lead to drying of its surface, ulceration, hypopyon and panophthalmitis Later, contraction of scar tissue in the face adjacent to the lids and orbit may result in ectropion and exposure ulceration of the cornea, and such must be borne in mind in designing the initial plastic repair

The superficial and deep extent of the tissue loss must be assessed carefully, and any late complications from contracture foreseen If the wound in the eyelids or the adjacent tissues of the face has healed in a malposition, all fibrous tissue must be excised thoroughly, the skin edges slightly undermined and the original defect reconstructed so that appropriate plastic repair may be planned

Burns of the eyelids—Tannic acid preparations are contraindicated in the treatment of burns of the lids, for the rigidity and contracture which they cause leads to corneal exposure In the case of first and second order burns some measure of coagulant action without tissue contracture may be effected by the following procedure

Clean the burn and adjacent skin with normal saline, remove oil and grease with soap, open any blisters and remove loose epidermis Paint the

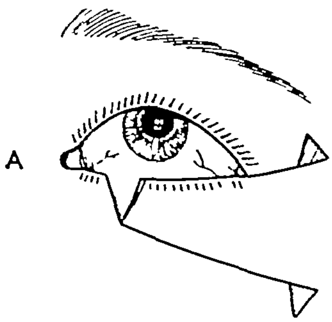
area with gentian violet (1 per cent) aqueous solution which is non irritant strongly bactericidal and analgesic but with poor powers of coagulation then wait five to ten minutes and apply silver nitrate (10 per cent) Gentian violet (1 per cent) is reapplied two or three times at fifteen minute intervals The eyes and eyelids are protected by a sterile wire gauze cage covered with a dry gauze dressing On the second day gentian violet is reapplied once or twice When B coli infect the burn gentian violet is replaced with a mixture of gentian violet acriflavine and brilliant green The eschar is very pliable does not crack at the skin folds or at the edges If it is adherent as is sometimes the case in third or deep second-degree burns surgical removal by excision under sodium pentothal anæsthesia and Thiersch grafting is indicated In the case of severe burns in which the skin is extensively destroyed down to or through the orbicularis muscle débridement followed by tarsorrhaphy and either Ollier Thiersch or Wolfe grafting is necessary The tarsorrhaphy may be left for two or three months, or longer until there is no clinical evidence of contracture When the whole thickness of the lid is destroyed one of the appropriate procedures described below will have to be undertaken (see Figs 804 805 and 806)

Conjunctival Burns—Small losses of conjunctiva may be remedied by undermining adjacent conjunctiva to fashion a sliding flap and suturing this forward over the denuded area or by turning a pedicle flap from the upper or lower fornix over the appropriate site In severe burns of the conjunctiva all devitalized tissue should be excised down to the sclera and in the case of large defects buccal mucous membrane grafts are necessary

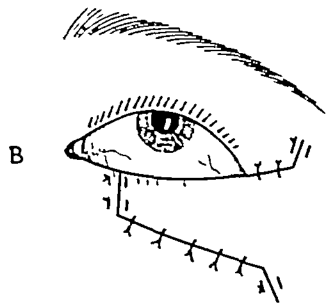
WOUNDS OF THE EYELIDS

The concussion effect of a large explosion may split the upper lid vertically for 5 or 6 mm Losses in skin are corrected by either Ollier Thiersch or Wolfe grafting and temporary tarsorrhaphy The Ollier Thiersch graft has the disadvantage that it remains white and may contrast somewhat obviously with the adjacent skin whereas the Wolfe graft particularly if the redundant skin of the opposite upper lid is used tones in well with the colour and texture of the lid skin Such a surgical procedure should be done if possible within two to six hours of the infliction of the wound Delay may allow pyogenic infection and the subsequent fibrosis cause considerable contracture Wounds involving a loss of the whole thickness of the lid require more elaborate plastic correction When the loss is less than one-third of the lid a sliding graft of the adjacent tissues, such as illustrated in Fig 804 may produce adequate anatomical and functional restoration The more extensive losses must be reconstructed on the *principles of* supplying a lining epithelium buccal mucous membrane if the eye is present or an Ollier Thiersch graft if the eye has been removed The supporting tissue of the lid is built up by burying in the graft either before or after *moving* it a shaving of auricular or costal cartilage If the perichondrium is left on one surface such a graft will bend so that the concavity is on the side of the perichondrium and this should therefore be the *inner surface* facing the eye Adjacent muscle fibres may be mobilized and introduced in the hope of obtaining some functional restoration

Upper-lid reconstruction—Fig 805 illustrates the case of total loss of the left upper lid To save the cornea from exposure ulceration it is



A, Partial loss of left lower lid Deficiency repaired by sliding graft Excision of skin represented by shaded triangle to facilitate sliding

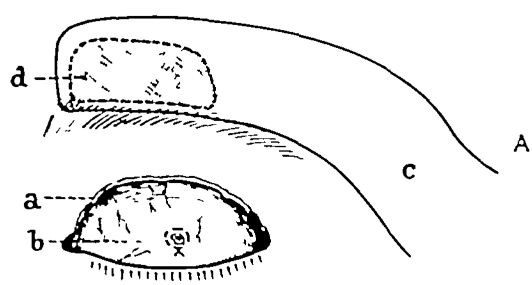


B, Sliding graft sutured in place

Fig 804

completely covered by undermining a conjunctival flap and securing it by a purse-string suture of No 1 silk, which holds for about eight days, after

A, Reconstruction of left upper lid *a*, Torn edge through base of upper lid *b*, Complete conjunctival flap over the cornea retained by purse-string suture *c*, Supra - orbital pedicle flap *d*, Buccal mucosa graft embedded beneath distal one third of pedicle



B, Pedicle graft swung into place *e*, Tarsorrhaphy mattress sutures Graft bed sutured

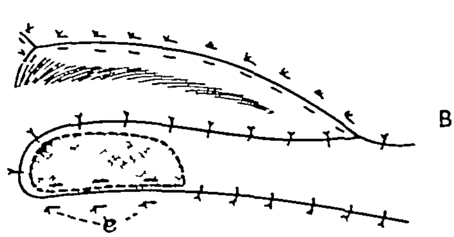
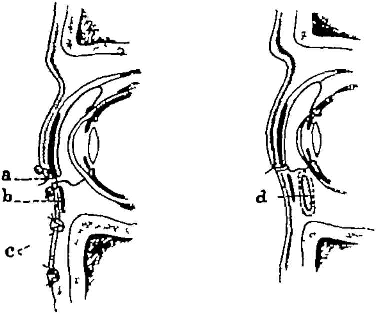


Fig 805

which the conjunctiva retracts to the limbus To keep this moist a continuous saline drip and the instillation of ol parolem drops is necessary The site for a pedicle graft above the left eyebrow is marked out in Bonney's

blue The lower margin of the incision includes a line of hairs from the upper margin of the eyebrow so that these may form a line of lashes in the new lid A piece of buccal mucosa to form the palpebral conjunctiva is folded over a thin strip of stent the appropriate size and shape and embedded beneath the skin at the extremity of the pedicle The stent is removed when the pedicle is cut and swung down into position Any buccal mucosa adherent to the bed of the pedicle is excised The time for swinging the pedicle into position has to be determined by the exposure of the cornea



A

Reconstruction of lower lid.

a Line of tarsorrhaphy Mattress sutures tied over rubber tubing b, Cartilage graft embedded c, Wolfe graft.

B

Reconstruction of lower lid.

d, Stent surrounded by mucous membrane graft embedded deep to cartilage graft to form lower fornix.

Fig 806

from the conjunctival flap giving way This may occur at any time between the fifth and the eighth day The conjunctival purse-string suture is removed the pedicle swung down and sutured in position and tarsorrhaphy is performed The pedicle bed is closed by undermining the scalp over the frontal region and inserting mattress sutures passed through rubber tubing to avoid cutting into the skin. Cosmetic adjustments on the pedicle may be made when the tarsorrhaphy is undone two to three months afterwards In order to obtain some mobility in the lid attempts may be made to separate some of the fibres of the orbicularis muscle and introduce these at a lower level into the substance of the lid and by searching for the tendon of the levator palpebræ superioris and advancing this on to the anterior surface of the cartilage graft previously inserted to build up the supporting tissue of the lid Failing this the central fibres of the superior rectus muscle

could be utilized, as in Motais' operation The eyebrow hairs on the lower margin of the graft require training to avoid trichiasis

Lower lid construction—Fig 806 shows the main steps and stages of an operation for replacing the lower lid When the upper lid is intact its margin is prepared at three sites for tarsorrhaphy to the opposed skin edge, which may require slight mobilization by undermining A strip of auricular or costal cartilage the size and shape of the lower tarsal plate is inserted deep to the fibres of the orbicularis muscle and adjacent to the lid margin, and covered over before completing the tarsorrhaphy Three weeks later a buccal mucous membrane graft, the depth and length of the lower palpebral and bulbar conjunctiva and the lower fornix, is folded smoothly over a glass or metal mould and inserted deep to the cartilage through a curved incision made in the length of the lower lid and 1 cm below the level of the tarsorrhaphy line Into the ellipse thus created a dermo-epidermic graft is inserted so that the hammock graft thus fashioned with the cartilage and buccal mucosa may move upwards Eight days later the tarsorrhaphy is temporarily undone and the mould removed by incising down to its upper edge in the plane of the palpebral conjunctiva The edges of the buccal mucous membrane graft are apposed to the bulbar conjunctiva and the lid margin and, if necessary, sutured It may be necessary at this stage to leave the eyelids open for forty-eight hours to ensure that the *cul-de-sac* is kept open and at the end of this time to remove any sutures inserted between the bulbar conjunctiva and the buccal mucosa and between the latter and the lid margin When this is satisfactory, tarsorrhaphy is again performed and left so for two or three months

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CHAPTER LXXIII

NON-PERFORATING INJURIES OF THE EYEBALL

INJURIES DUE TO CHEMICAL WARFARE

ALL the gases used in modern war have an effect on the eyes but of these only two mustard and lewisite are known to produce serious ocular lesions The lachrymators (i) *ethyliodoacetate* K S.K. (ii) *bromobenzylcyanide* B B C and (iii) *chloroacetophenone* C.A.P cause in concentration immediate irritation of the eyes a stinging sensation and a profuse lachrymation. In the higher concentrations blepharospasm is evident The conjunctiva is injected and swollen but there is no involvement of the cornea These ocular symptoms disappear in a few hours the eyes respond well to treatment by lavage with simple lotions and there is no residual neurasthenia

The sensory irritants—arsenical compounds the asphyxiants phosgene and chlorine and the smokes —also cause mild conjunctivitis

Mustard may be used as a spray from aeroplanes in shells bombs mortars and grenades Lewisite (β-chlorovinyldichloroarsine) which is similar to it in some respects was not used in the 1914 18 war The arsenic in it is a systemic poison is absorbed through the skin and lungs and has been recovered from the urine and tissues of experimental animals Lewisite is more rapidly irritant than mustard has an early sensory irritant action and the eye symptoms are therefore more severe

OCULAR PROTECTION

Against these poison gases the soldier has his service respirator the eyepieces of which are made of non-splinterable glass 4 mm thick the headpiece is air tight and that together with the box filter gives him secure protection against mustard and lewisite vapour

In the forward areas he must wear an eye-shield made of cellulose acetate which protects his eyes from droplets and splashes of liquid mustard

MUSTARD GAS

Mustard gas is a severe chemical irritant to living tissues with which it forms highly toxic by products of disintegration It has been suggested that it combines with the free amine groups of the protein molecules and forms a stable toxic substance With rare exceptions the reaction of a minute drop of mustard (oil 0·004 c c) on the eyes of man is followed by an immediate intense and rapid reaction which seems to be quite unaffected at this stage by any local treatment known up to the present

Mustard possesses a degree of liposolubility, but is relatively insoluble in water, at 10° C this is 0 07 per cent, and at body temperature 25 per cent of mustard in such a solution is hydrolysed in three minutes This reaction is not accelerated by alkalis It is, however, doubtful if hydrolysis in the conjunctival sac plays much part in reducing the severity of the lesion Mustard is more readily absorbed by the cornea than by the skin Except for its peculiar and specific intracellular reaction it is not an active substance chemically

Mustard vapour in as low a concentration as 1 10,000,000 in air produces ocular symptoms and signs after a delay varying from two to forty-eight hours in the majority of cases these occur six to eight hours after exposure, but with the more concentrated vapour the effect is immediate

The interaction of mustard with the secretions of the eye causes an alteration which leaves the mustard inactive as such fifteen minutes after it has entered the conjunctival sac The instillation of such secretions into the eye of an experimental animal is without effect After the initial reaction an oxidation process probably occurs

Symptoms and signs—The severity of the ocular injury depends on the concentration and the length of time of exposure to the gas The action of mustard may be cumulative, and with the modern methods of liberation the proportion of severe cases will probably be increased The ocular injury caused by mustard is slowly progressive, and in more severe burns there is a marked delay in healing analogous to an X-ray burn

OCULAR INJURY FROM MUSTARD VAPOUR—1 *Cornea not visibly affected*—There is a sense of grittiness under the lids and pain in and around the eyes Photophobia, blepharospasm and lachrymation follow In the slight or moderately severe cases the bulbar conjunctival vessels in the interpalpebral zone are congested and the conjunctiva swollen

Functional photophobia may persist after all inflammatory signs have disappeared, and an anxiety state and fear of blindness may delay convalescence In the 1914-18 war about 75 per cent of the mild cases returned to duty in one to four weeks, and in 15 per cent of moderately severe cases in which there was no corneal damage there was a recovery in four to six weeks (Figs 807 to 810)

2 *Cornea appreciably damaged*—In these cases photophobia, blepharospasm and lachrymation are severe The interpalpebral zone of the bulbar conjunctiva is white from a coagulated exudate, the pressure of which obliterates the capillaries Above and below this chemotic conjunctiva bulges forward from the fornices The lids become swollen, red and adherent with sticky discharge and crusts Across the cornea there is a wide band-like opacity continuous with the whitened interpalpebral bulbar conjunctiva

The cornea is stippled (" orange skin "), the corneal reflex is irregular, the corneal epithelium œdematous and roughened, later it becomes exfoliated and there is diminished corneal sensation which persists for weeks The pupil is constricted as a result of irritation

Secondary infection from pyogenic micro organisms, corneal ulceration, hypopyon and panophthalmitis are complications which may follow within four or five days of the injury, and have to be guarded against as far as possible Chest complications may reduce the reparative process. A neurasthenic state sometimes complicates the convalescence

OCULAR INJURY FROM MUSTARD OIL DROPS—The effect of a minute drop of mustard splashed into an eye is an intensification of the above symptoms

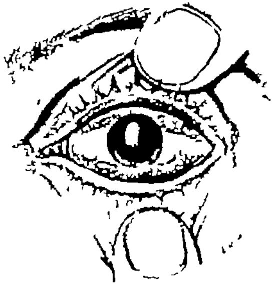

FIG. 807
Severe burn in acute stage

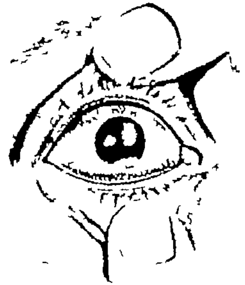

FIG. 808
Severe burn complicated with hypopyon ulcer

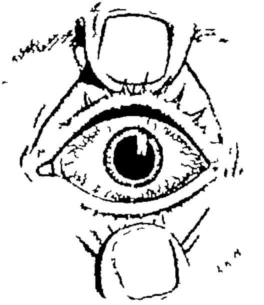

FIG. 809
Stage of resolution in mustard-gas injury to the eye showing absorption of coagulative exudate. Cornea has recovered its lustre

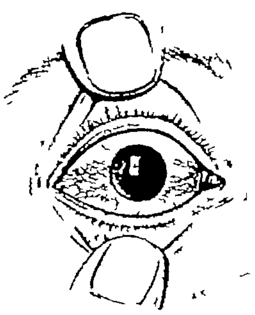

FIG. 810
Stage of convalescence

(*Medical Manual of Chemical Warfare* H.M. Stationery Office London, 1939)

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The interaction of mustard with the secretions of the eye causes an alteration which leaves the mustard inactive as such fifteen minutes after it has entered the conjunctival sac The instillation of such secretions into the eye of an experimental animal is without effect After the initial reaction an oxidation process probably occurs

Symptoms and signs—The severity of the ocular injury depends on the concentration and the length of time of exposure to the gas The action of mustard may be cumulative, and with the modern methods of liberation the proportion of severe cases will probably be increased The ocular injury caused by mustard is slowly progressive, and in more severe burns there is a marked delay in healing analogous to an X-ray burn

OCULAR INJURY FROM MUSTARD VAPOUR—1 *Cornea not visibly affected*—There is a sense of grittiness under the lids and pain in and around the eyes Photophobia, blepharospasm and lachrymation follow In the slight or moderately severe cases the bulbar conjunctival vessels in the interpalpebral zone are congested and the conjunctiva swollen

Functional photophobia may persist after all inflammatory signs have disappeared, and an anxiety state and fear of blindness may delay convalescence In the 1914-18 war about 75 per cent of the mild cases returned to duty in one to four weeks, and in 15 per cent of moderately severe cases in which there was no corneal damage there was a recovery in four to six weeks (Figs 807 to 810)

2 *Cornea appreciably damaged*—In these cases photophobia, blepharospasm and lachrymation are severe The interpalpebral zone of the bulbar conjunctiva is white from a coagulated exudate, the pressure of which obliterates the capillaries Above and below this chemotic conjunctiva bulges forward from the fornices The lids become swollen, red and adherent with sticky discharge and crusts Across the cornea there is a wide band-like opacity continuous with the whitened interpalpebral bulbar conjunctiva

The cornea is stippled (" orange skin "), the corneal reflex is irregular, the corneal epithelium œdematous and roughened, later it becomes exfoliated and there is diminished corneal sensation which persists for weeks The pupil is constricted as a result of irritation

Secondary infection from pyogenic micro organisms, corneal ulceration, hypopyon and pan ophthalmitis are complications which may follow within four or five days of the injury, and have to be guarded against as far as possible Chest complications may reduce the reparative process A neurasthenic state sometimes complicates the convalescence

OCULAR INJURY FROM MUSTARD OIL DROPS—The effect of a minute drop of mustard splashed into an eye is an intensification of the above symptoms

The German first-aid treatment consists in irrigation with saturated boric acid, the application of sodium bicarbonate ointment and the use of pilocarpine drops and pituitary extract Saturated boric acid is more irritating than sodium bicarbonate

ROUTINE TREATMENT—At present there seems to be no more satisfactory lotion for irrigating the eyes and removing desquamated cells and discharges than sodium bicarbonate 2 per cent pH 8·0 Down Bros have made a self retaining irrigating speculum (Fig 812) which allows the interpalpebral aperture to be opened to about one third of its normal extent and streams of lukewarm lotion to be directed into the upper and lower fornices Atropine or hyoscine are necessary when the cornea is involved

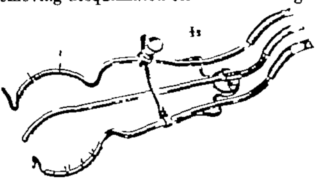

FIG 812
Self retaining irrigating speculum.

Cod liver oil drops with or without vitamin A are of value in assisting corneal regeneration and checking keratitis These drops require no sterilization

TREATMENT OF SECONDARY INFECTION—The micro-organisms of secondary infection are evident in some cases between the fifth and eighth days. Livingston and Walker recommend the use of merthiolate 1 10,000 with a diffusing factor and found that the optimum period of value was five to seven days If merthiolate drops were used after this, ocular congestion recurred.

Warthin and Weller claim that dichloramine T 0·5 per cent. in chlorcosane (chlorinated medicinal paraffin) is of value in dealing with secondary infection pyogenic organisms. Such a solution is only stable for three days and should not be used if there is a precipitate The French eye surgeons favour methylene blue 0 5 per cent and scarlet red 3 per cent. to deal with non-specific infections

TREATMENT OF LATE COMPLICATIONS—Some years after mustard gas injury with corneal damage the incidence of recurrent corneal ulceration may be reduced, the patient rendered more comfortable and his cornea protected by the use of contact glasses filled with ol paraloin and applied to the eyes These glasses also correct any irregular astigmatism and thereby improve the vision appreciably

* * * * * * * * *

It is probable that if mustard gas is used in the present war a number of new therapeutic agents will be tried out. The use of tarsorrhaphy at an appropriate stage may prove to be of value in preventing or reducing the incidence of late attacks of recurrent corneal erosion. Sulphonamide drops on to the cornea and conjunctiva, and excision of devitalized conjunctiva and episclera down to the sclera and up to the limbus with buccal mucous membrane graft replacement must await trial on human patients before any definite opinion can be given about their value

CONTUSIONS AND CONCUSSIONS

The eye lesions caused by missiles which do not perforate its tunics vary from a minute corneal abrasion or impaction of a small foreign body to rupture of the sclera or cornea and considerable disorganization of the globe

FOREIGN BODIES

The impaction of foreign bodies composed of sand earth steel copper and iron fragments glass and stone often affects both eyes and the foreign bodies are multiple Those which are accessible are removed as early as

within a few seconds of the accident Loss of corneal epithelium and spreading keratitis occur Symblepharon, secondary infection with pyogenic micro-organisms, hypopyon and panophthalmitis are complications

The residual signs of mustard gas injury to an eye are dilated, tortuous, varicose, dark-coloured conjunctival vessels in the interpalpebral zone 3 or 4 mm adjacent to the limbus These vessels show calibre irregularity and are embedded in a greyish-white matrix of scar tissue The appearance is "marble" like It is probable that some impairment of blood supply at this site affects the cornea, the sensation of which is impaired in some cases Greyish opacities are present in the cornea and these cause irregular astigmatism and reduction in visual acuity when near the centre Recurrent corneal ulceration occurs in some of these cases

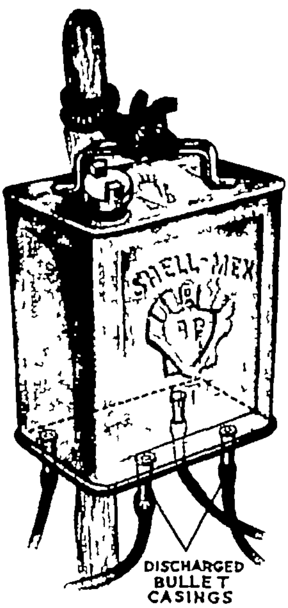

FIG 811

Two gallon petrol tin—improvised container in the field for anti-gas eye lotion Four perforated discharged bullet casings soldered into base of tin and connected by rubber tubing to irrigator nozzles Tin mounted on a standard inserted into the ground

Treatment—FIRST-AID TREATMENT—Although early local eye treatment of the injured men in the field may be of little avail in saving corneal tissue already badly damaged, an attempt to do a simple irrigation, to instil pantocain (local anæsthetic drops which do not damage the corneal epithelium nor delay its regeneration, as does cocaine) and cod-liver oil drops into the eyes and to provide clean tinted eye-shields may help to prevent panic among the casualties whose swollen and adherent eyelids often lead them to imagine that they are blinded The sight of injured men without attention and obviously distressed has a demoralizing effect on the troops moving forward The above treatment may be given by means of an improvised field irrigator

An improvised irrigator (Fig 811)—An irrigator is improvised by taking an empty 2-gal petrol tin, boring four holes in its bottom, each sufficient in size to admit the base of a discharged bullet case, the cap of which has been perforated The bases of these four bullet cases are soldered into the tin, making water-tight junctions The whole tin is cleaned and sterilized To the projecting extremities of the bullet cases 4½ ft of rubber tubing is attached, and into the free ends of these are inserted metal irrigator nozzles, each with a lever switch control to cause or stop the flow of lotion The tin is suspended from a 6-ft wooden stake driven into the ground, and each of the four irrigator tubes is operated by a trained orderly A suitable quantity of sodium bicarbonate is carried by the unit, and with boiled water it is made up into a 2 per cent solution Allowing three minutes for the treatment of both eyes (one and a half minutes for each eye), one team of orderlies with one irrigator could treat eighty men in an hour In heavily contaminated cases the personnel carrying out the treatment will have to work in anti-gas clothing and respirators and the wounded pass through a decontamination and cleansing centre In the advanced areas badly injured men may be led in files, connected by ropes or sticks, by a sighted guide from the field ambulance

In recent cases where the vitreous and intra-ocular structures are not grossly diseased, and where retinal tears and holes are seen and carefully localized, there is a reasonable prospect of replacing the retina by operation The sclera over the site of a hole is exposed and surface diathermy is applied by means of a 3 mm diameter electrode to the sclera at contiguous points around the site of the hole 70 to 100 milliamps for seven seconds This procedure induces areas of aseptic choroido retinitis The sclera and choroid are then punctured several times by a diathermy needle 40 milliamps for three seconds, and the inter-retinal fluid between the retinal pigment epithelium and the layer of rods and cones is sucked out through these perforations For three weeks the patient s head is placed immobile in bed in such a position that gravity may facilitate the drainage of the inter retinal fluid and the vitreous may press the retina against the choroid firm adhesions forming between these two membranes and the retinal tear becoming sealed no longer permits fluid to seep through it

For full details of treatment and prognosis the monographs and literature should be consulted

OPTIC NERVE

Avulsion of the optic nerve may be caused by large missiles spent shrapnel fragments of shell and several bullets entering the orbit

The concussion changes in the eye may indicate exactly the track of a missile and thus assist the general surgeon when there is some associated head injury In fractures involving the optic foramen and canal bone fragments may lacerate or completely sever the optic nerve

SCLERA

Missiles traversing the orbit without striking the eye may produce scleral ruptures on the opposite side to the point of impact For instance a missile on the temporal side caused a large equatorial rupture on the nasal side and another traversing the back of the orbit led to a corneal rupture which extended into the anterior part of the sclera

The common site of scleral rupture when the eye is struck from the front by a blunt object is in the upper nasal quadrant about 3 mm behind and concentric with the limbus Increased depth of the anterior chamber and lowered intra-ocular pressure are associated signs of rupture of the globe Dislocation and even extrusion of the lens prolapse of vitreous and the uveal tract and intra-ocular hæmorrhage are complications in some cases In many cases it is worth while attempting some conservative surgery by turning back an adjacent conjunctival flap placing atraumatic eyeless sutures in the edges of the scleral wound performing wound toilet with abscission or replacement of any prolapsed intra-ocular structure closing the wound by tying the scleral sutures and covering it with the conjunctival flap

INTRA-OCULAR HÆMORRHAGE

Following contusion or concussion of the eye hæmorrhage may take place into the anterior chamber the vitreous retina choroid, beneath the

Following the passage of a missile through the orbit there occur on the side of the impact, or on the opposite side of the fundus, or at the macula, large areas of dark-red hæmorrhage and glistening white areas At the macula and in the posterior half of the fundus these areas become organized into slightly raised white plaques of fibrous tissue uniting the retina and choroid, and having a ragged edge fringed with pigment At the affected site there is a scotoma Retinal detachment and progressive loss of vision do not occur The case is different with retinitis proliferans, in which disorder organization of vitreous and retinal hæmorrhage, and the formation of

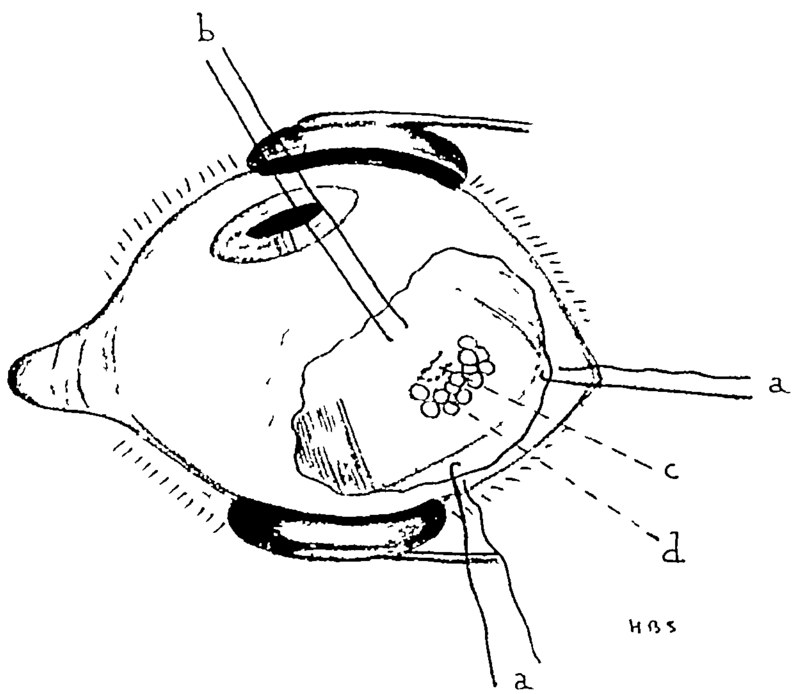

FIG 814

Retinal detachment Left eye *aa* are sutures retracting the posterior edge of the conjunctival incision, *b* is a traction suture drawing the globe upwards and inwards, *c* is a dotted line on the sclera indicating the site of a large crescentic tear at the ora serrata in the 4 30 o'clock meridian The insertions of the external and inferior recti muscles are exposed, *d* is the barrage of surgical diathermy, surface and perforating, applied to the sclera

fibrillar connective tissue adherent to the optic disc and retina, and the proliferation of Muller's fibres ultimately contract and cause retinal detachment

The treatment of the fundus lesions consists in rest in bed, atropine, dark glasses and such time-honoured therapeutic procedures as hot vapour baths, potassium iodide and mercury inunctions, applied with the object of aiding absorption of the hæmorrhages and exudates

Retinal detachment may be caused by a concussion injury, inter-retinal hæmorrhage between the retinal pigment epithelium and the layer of rods and cones, as a sequel to vitreous loss and hypotony, associated with cicatricial contraction after a perforating scleral wound and as a result of shrinkage of the vitreous body (Fig 814)

In recent cases where the vitreous and intra-ocular structures are not grossly diseased, and where retinal tears and holes are seen and carefully localized there is a reasonable prospect of replacing the retina by operation The sclera over the site of a hole is exposed and surface diathermy is applied by means of a 3-mm diameter electrode to the sclera at contiguous points around the site of the hole 70 to 100 milliamps for seven seconds This procedure induces areas of aseptic choroido retinitis The sclera and choroid are then punctured several times by a diathermy needle 40 milliamps for three seconds, and the inter retinal fluid between the retinal pigment epithelium and the layer of rods and cones is sucked out through these perforations For three weeks the patient s head is placed immobile in bed in such a position that gravity may facilitate the drainage of the inter retinal fluid and the vitreous may press the retina against the choroid firm adhesions forming between these two membranes and the retinal tear becoming sealed no longer permits fluid to seep through it

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Following contusion or concussion of the eye hæmorrhage may take place into the anterior chamber the vitreous retina choroid beneath the

hyaloid membrane, between the layer of rods and cones and the retinal pigment epithelium and in the suprachoroidal lymph space

If a hyphæma is total, or nearly so, and is causing secondary glaucoma and blood-staining of the cornea, it should be evacuated by paracentesis and wash-out of the anterior chamber Generally the blood enters the anterior iris crypts and is absorbed by the stroma

A vitreous hæmorrhage is treated by rest and absorptive measures

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CHAPTER LXXIV

PERFORATING WOUNDS OF THE EYEBALL

PERFORATING wounds of the eyeball whether accompanied or not by the retention of a foreign body are fraught with danger not only by the mechanical injury produced but also by the infection that is so often introduced The diagnosis of a perforation may be quite easy but there are cases which need close examination to reveal the perforation and it must be borne in mind that a perforating wound either by a sharp instrument or a small flying fragment may not show itself upon the surface of the globe at all, as it is possible to pierce the coats of the eye through the lower lid behind the conjunctival fornix and unless a careful routine examination is carried out in every case the fact that the sclera has been perforated may be overlooked.

History of the case will usually give a clue to the character of the perforating object but the observer must be careful not to be misled by the opinion of the patient as to what has hit the eye as we shall see subsequently when dealing with foreign bodies retained within the globe

Routine examination—1 The eyelids and eye should be carefully examined for a wound If in the cornea there may be immediately behind it a hole in the iris and subsequent investigation will probably disclose a wound of the lens If the wound be scleral it may be covered by a subconjunctival hæmorrhage A wound of a conjunctival vessel will cause a bright red extravasation of blood beneath the conjunctiva so often seen apart from injury to the eye by a sharp instrument If episcleral branches of anterior ciliary vessels are injured, the colour of the hæmorrhage is much deeper and is obscured by episcleral tissue If therefore the eye has received an injury such as produces a wound of episcleral vessels the observer should bear in mind the possibility that this hæmorrhage hides a wound of the sclera

2 Loss of intra-ocular contents will cause a fall of intra-ocular pressure With a wound of appreciable size at any rate in the early hours after the injury this will be obvious when the eye is gently palpated A small perforation by a flying fragment may not be enough to cause appreciable loss of tension and in cases in which a scleral wound is obscured by a subconjunctival hæmorrhage this sign may be of little value If there has been considerable loss of vitreous besides a great fall of intra-ocular pressure the anterior chamber will have an abnormal depth

3 Prolapse of uveal tissue and the deformity produced in the iris as a consequence is a sure sign that the globe has been perforated.

4 In wounds of the sclera not necessarily extensive a prolapse of vitreous is commonly seen and it may be recognized by its viscid character

When the wound is a few days old the prolapse becomes grey and stringy, and the observer should not mistake it for a loose shred of conjunctiva A gross loss of vitreous causes a marked increase in the depth of the anterior chamber

5 Loss of aqueous humour besides causing a reduction in the tension of the eye, leads to shallowness of the anterior chamber or even to its complete obliteration If some hours have passed since the injury, however, the anterior chamber may have re-formed, and this is often seen when there has been a very small perforation

6 Reduction of visual acuity Every examination of an injured eye should include a note of the visual acuity, which should be compared with that of the uninjured eye Sir William Bowman laid it down that in every case of injury to the eye however apparently trifling the vision should always be recorded

7 The pupil should be fully dilated, the instillation of atropine being supplemented by a subconjunctival injection of 3 minims of a solution of adrenalin hydrochloride (1 1 000) at the limbus, and the media and fundus examined with an ophthalmoscope

8 When the pupil has been fully dilated the eye should be carefully examined with a slit-lamp In case of injury to the eye the slit-lamp is particularly useful it will reveal at once whether a wound of the cornea has completely perforated its substance whether a foreign body in the cornea is projecting into the anterior chamber or whether there is a hole in the iris, it will distinguish a traumatic opacity of the lens from one that was present before the injury and if there has been a prolapse of vitreous, however small, it will show the framework of the vitreous drawn towards the perforation

9 Finally, in any case of doubt an X-ray photograph should be made, a stereoscopic X-ray examination is the only one of value in most cases this will also allow a localization of a foreign body to be made and settle any doubt as to whether a foreign body is within the globe or not

A PERFORATING WOUNDS WITHOUT THE INCLUSION OF A FOREIGN BODY

1. **When there is no prolapse of ocular contents**—CONJUNCTIVAL WOUNDS —All perforating wounds of the conjunctiva should be repaired with fine silk If this be neglected the episcleral tissue becomes infected, and there will be extruded through the gap in the conjunctiva a button of granulation tissue which will need removal followed by suture of the conjunctiva at a later date

CORNEAL WOUNDS—A *wound short of perforation* of the cornea heals readily provided it is not infected. If there is a flap of corneal tissue which has not been completely detached, it should be carefully replaced after the eye has been cleaned with a normal solution of sodium chloride Atropine should be put into the conjunctival sac and the eye bandaged If signs of infection appear the case then becomes one of corneal ulcer in its treatment Signs of infection will be increased injection of the eye greyness and infiltration of the corneal wound and the surrounding area haziness of the aqueous humour with possibly hypopyon and all the signs of an acute iritis

i.e. dullness, alteration in colour and loss of pattern of the iris. When the infection is severe the corneal wound will need infiltrating with pure carbolic acid with a corneal gouge, the infiltration being carefully controlled by mopping up any excess with small angular pieces of blotting paper. The eye will need frequent irrigation with a solution of oxycyanide of mercury (1 : 10 000) with equal parts of warm water, and the use of liquor atropinæ sulphate (1 per cent.) or unguentum atropinæ (1 per cent.) every four hours. It will need judgment as to whether a pad and bandage should be used, and if there is profuse discharge these should be abandoned. The patient should be kept in bed.

Hot bathing—Heat, as in other parts of the body, is one of the most useful forms of treatment of an inflammatory disease of the eye, but in the case of the eye the method of application has to be specially adapted. Heat cannot be applied in the form of a fomentation, as the pad is so small that it loses most of its heat before it can be applied, and so a method called hot bathing has been introduced. So as to carry out this manœuvre, there are needed a source of boiling water, a small basin, such as a pudding basin, two small wooden cooking spoons, a pad of Gamgee tissue and a short piece of bandage. The pad of Gamgee tissue is tied to the convex surface of one of the spoons and the basin is then half-filled with boiling water. The spoon with the Gamgee tissue is then dipped into the basin and wrung until as dry as possible by pressure of the concave surface of the other spoon and then, as soon as it can be borne, the Gamgee tissue is applied to the closed lids of the affected eye. As soon as the temperature has fallen the process is repeated and carried out for ten minutes every four hours. Care must be taken not to scald the eyelids. When hot bathing has been concluded, the conjunctival sac is irrigated with a lotion of about 100° F. and then atropine instilled. Unless contraindicated, a warm pad of Gamgee tissue is bandaged lightly to the eye. This method of hot bathing can be carried out by the patient. If it be considered advisable for the nurse to perform the treatment, she can prevent making her fingers tender by using a rubber glove and then, squeezing a pad of Gamgee as dry as possible, lay it gently upon the closed lids. While this pad is cooling a second pad immersed in the boiling water can be prepared. It is sometimes useful to incorporate with the Gamgee tissue applied to the eye as a pad, an electric heater that may be worn in the intervals of hot bathing. There are two forms in common use: one introduced by Maddox, consists of a coil of German silver wire wound round a pad of asbestos and covered with flannel which, controlled by a resistance, can be incorporated with the Gamgee tissue pad; in the other, the heating mechanism is contained in a metal container placed upon the eye-pad and worked direct from the electric current.

If the *wound has completely perforated the cornea*, not only may we have to deal with infection of the cornea, but also with infection carried into the eye. An examination with the slit-lamp will immediately disclose how deep the corneal wound is. If the infection be not very virulent, the outlook is good always provided that the lens or vitreous is not injured. The treatment of a simple perforation of the cornea is that of a non-perforating wound.

There is evidence to indicate that, as in infection elsewhere, the use of sulphanilamide or M. & B. 693 exerts a beneficial effect on the course of the inflammation in infected wounds of the eye. This applies both to intra-ocular infections and to non-penetrating wounds.

The sulphanilamide may be given internally in tablets and also applied locally as drops or ointment.

Scleral wounds—If there is a scleral wound without prolapse of uvea or vitreous, the hole in the sclera must be covered by drawing the edges of the perforated conjunctiva together. This will be described when dealing with perforating wounds complicated by prolapse of ocular contents. It is to be emphasized that no attempt should be made to stitch the edges of the sclera itself.

2. **When there is prolapse of uveal tissue**—If a perforating wound is

complicated by the prolapse of uveal tissue, the injury becomes much more grave and surgical interference urgently necessary The aim in the treatment and management of such cases is to leave the eye with merely a perforating wound, and no uveal or other tissue within its lips It is rarely possible to repose prolapsed uvea, and it is usually unwise, because the prolapse has become infected and its return to the eye dangerous If prolapsed uvea is left incarcerated in the perforating wound, one or other of the following conditions will result —

(*a*) There will be delay in the healing of the wound and prolonged inflammation and irritability of the eye

(*b*) The wound will never properly consolidate, but a weak, so-called cystoid scar will result which may stretch before the intra-ocular pressure

(*c*) The pupil may be displaced, leading to unsightliness and to defective vision not only because of the lateral position of the pupil but also in consequence of the irregular astigmatism caused by the altered curvature of the cornea Thus a bulging peripheral scar of the cornea will cause flattening of the cornea in this meridian Even where prolapsed uvea has been removed it is usual to have some irregular refraction produced in the cornea just as is seen constantly following extraction of cataract, which, after all, involves a perforating wound in which prolapsed uvea has been avoided

(*d*) Iridocyclitis Some inflammation of the iris and ciliary body is expected in all injuries of the eye, be they produced by blunt or sharp objects, but when uveal tissue is incorporated in a perforating wound this will take much longer to subside and is a menace to subsequent usefulness of the eye

(*e*) Sympathetic iridocyclitis Not only may serious iridocyclitis occur in the injured eye but inflammation may, in some manner, be set up in the other eye This is the greatest catastrophe in ophthalmology, because it leads not only to blindness in the injured eye but, as the prognosis is so bad, to probable blindness in the other It is because of the possibility of the outbreak of sympathetic iridocyclitis that the skilful treatment of perforating injuries is of such great importance Great judgment is needed in deciding how long one may retain an injured eye with safety, since the treatment of sympathetic iridocyclitis once it has become established, is almost universally unsatisfactory, and the only method that is safe and satisfactory is preventative, namely, removing the injured eye before iridocyclitis has become established in the other

TREATMENT

It will be convenient to divide cases of perforating injuries complicated by prolapsed uvea into three groups —

1 Cases in which the wound is purely corneal
2 Cases in which the wound is at the corneo-scleral margin
3 Cases in which the wound of the cornea extends beyond the limbus into the sclera

1 Cases in which the wound is purely corneal.

Anæsthesia—It was previously necessary to give all cases a general anæsthetic, as sufficiently deep anæsthesia of the eye could not be produced by the use of cocaine drops, and the operator needed to be very deliberate whilst operating If he feared that he was about to give the patient pain he might not be so thorough as he should be and so fail in his attempt to free perforating wounds from incarcerated uvea. It is possible to produce perfect anæsthesia of the globe by means of a retrobulbar injection of novocain, and it is usually wise also to paralyse the orbicularis muscle especially when dealing with an apprehensive and nervous patient. With children, and when a general anæsthetic is judged necessary an intravenous injection of evipan or similar drug is particularly suitable

THE O'BRIEN METHOD OF BLOCKING THE FACIAL NERVE IN FRONT OF THE TRAGUS—Two cubic centimetres of a 2 per cent solution of novocain are injected by means of a needle 1¼ in long. The point of injection is just anterior to the tragus of the ear below the posterior portion of the zygomatic process. Going straight inward with a sharp needle one strikes the bony condyloid process at a depth of about 1 cm. As soon as the bone is felt with the needle begin injecting the novocain solution, and gradually withdrawing inject about 2 c.c Signs of paralysis of the orbicularis muscle should appear in five minutes.

RETROBULBAR INJECTION—For this there is needed a 2 c c. hypodermic syringe a fine needle 3 5 cm. long with a short cutting point and a 2 per cent. solution of novocain. Some prefer a mixture of a 2 per cent solution of novocain and a 2 per cent. solution of percaine in equal amounts. The advantage of percaine is that it prolongs the anæsthesia for twenty four hours. A freshly prepared solution must be employed, because an old solution of percaine loses its efficiency It is prepared thus: To 30 cm. of a solution of novocain (2 per cent.) add 1 cgm. of percaine in tablet form. Anæsthesia is complete in fifteen to twenty minutes

The needle is entered at the site of the infero-external angle of the orbit, a little below the tendon of the orbicularis. The needle should be directed backwards and slightly upwards, in the direction of the ciliary ganglion (Fig 815) It penetrates at first without resistance then a slight jump indicates that the point of the needle has pierced the capsule of Tenon behind the eye Before injecting the fluid, withdraw the plunger a little to make certain that a blood vessel has not been pierced. The injection may then be made and, after this, firm pressure is made to compress the orbit for a few seconds. In case of an infected wound of the globe pressure should usually be avoided.

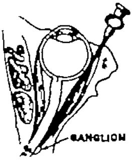

FIG 815

Illustrates the path of the needle during the injection of a solution of novocain for producing local anæsthetization of the globe One injection below the external palpebral ligament with a needle 3 5 cm. in length suffices for ordinary intraocular operations.

The result of the injection is to cause paralysis of most of the extraocular muscles. Often the superior rectus escapes, and it is an advantage to inject 5 minims of the solution into the muscle itself, especially when it is decided to use a superior rectus suture This injection also makes it possible to carry out any ordinary surgical procedure on the eye without pain

For an excision of the eye a more extensive infiltration with novocain is necessary First a 4 5 cm. needle is used, secondly three injections, each of 1 c.c., are used one is injected after inserting the needle through its whole length below the tendon of the orbicularis, another through the upper and inner part of the palpebral fascia of the upper lid and a third through the middle of the palpebral fascia of the lower lid (Fig 816)

FIG 816

Shows the site of injection of novocain with a 4 5 cm. needle for an anæsthetization of the eye preliminary to enucleation of the globe

A premedication consisting of a subcutaneous injection of $\frac{1}{150}$ gr of hyoscine hydrochloride and $\frac{1}{4}$ gr of morphine sulphate two or three hours before operation is in suitable cases of great convenience Alternatively 2 gr of luminal may be given in 1 gr doses three hours and one hour before operation.

These cases are usually the easiest to treat and also the most satisfactory especially when uncomplicated by a wound of the lens or the retention of a foreign body In the absence of infection they have a very good prognosis provided the case comes under observation soon after the accident If there is any difficulty in keeping the injured part of the cornea in the middle of the area exposed by the speculum a stitch through the superior rectus muscle is convenient and gives perfect control of the eye as traction upon the suture does not cause the wound to gape as it does with the pressure produced by fixation forceps

The prolapsed knuckle of iris is seized with toothed iris forceps and held in the right hand (if the operator be right-handed, but with the left hand if he be left-handed) and the iris pulled gently in all directions from side to side, towards and away from the ciliary attachment. The result of these manœuvres is watched, and when the iris is perfectly freed, and whilst gentle traction is maintained by the iris forceps, the whole prolapse is seized in the plane of the anterior surface of the cornea with Couper's capsule forceps. The iris forceps are put on one side and, whilst gentle traction is exerted by the capsule forceps, the prolapsed iris is removed by cutting through it with de Wecker's scissors, gently pressing them upon the surface of the cornea whilst cutting (Fig. 817). The whole prolapse must be removed by one snip of the scissors, as hæmorrhage is likely to follow which will fill the anterior chamber and obscure its contents; this makes dangerous any further attempt at freeing the iris owing to the unprotected condition of the lens capsule. If the operation has been successful the cut margins of the iris slide back into the eye, leaving a coloboma with the pillars free.

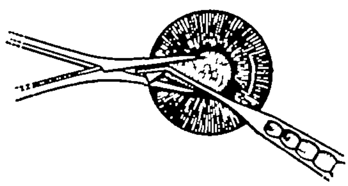

FIG. 817.

The use of Couper's capsule forceps and de Wecker's scissors in the removal of prolapsed iris through a corneal wound. On the right hand side is the small corneal incision, recommended for the introduction of an iris repositor.

What has been done, in effect, is this: iris tissue not previously prolapsed has been withdrawn from the eye, and whilst the iris has been put on the stretch, a cut has been made with the scissors into the healthy iris tissue withdrawn from the eye by the operator.

Wounds of the cornea are not always produced by a sharp instrument entering the eye radially; they are often caused by one entering the eye tangentially like a keratome incision, and they may be not only valve-like but irregular and jagged. In such cases the freeing of the iris from the wound is much more difficult. In the case of a valvular wound it is not difficult to free the iris that has followed the path of withdrawal of the perforating instrument, as a repositor can be introduced into the eye in the same plane and direction in which the perforating object entered the eye, but the repositor cannot be made to engage that portion of the iris that lies under the lower lip of the wound, and consequently that pillar of the coloboma may be left engaged in or adherent to the wound in the cornea. The difficulty may be overcome in the following manner. Before attempting to free the prolapsed iris, and while there is still an anterior chamber, an incision 3 mm. long is made in the cornea, 3 mm. within the limbus and immediately opposite the prolapse, to which the point of the broad needle is directed. When this has been done the prolapsed iris should be dealt with in the manner described, and after that an iris repositor may be introduced into the eye through the corneal incision and any iris still engaged in the original wound reposed from within the eye. If a magnetic foreign body has been removed from the eye before dealing with the prolapsed iris, the incision through which the foreign body was removed may be used for inserting the iris repositor.

It may happen that a given case of prolapsed iris may not reach the surgeon for several days after the accident. Depending upon the interval between the receipt of the injury and the day on which

the case comes for treatment difficulties will be met with when an attempt is made to remove the prolapse It is not possible to say at what date after the receipt of an injury that removal of a prolapse becomes impossible each case must be considered separately but cases can usually be treated up to ten days, and in exceptional circumstances a prolapse of iris may be successfully removed fourteen days after the perforation.

If more than a day has passed since the injury the prolapsed iris will be covered with lymph and the lips of the wound soft friable and grey with infiltration. A stream of warm saline lotion should be directed to the prolapsed iris by means of an anterior chamber irrigator and any exudate gently teased away with an iris repositor The stream of lotion will make the prolapsed iris more easily seen. It has at this stage lost its pigment and will appear as a delicate whitish pellicle which may be propelled in various directions by the force of the stream. When the operator knows the extent of the prolapse it is seized with iris forceps and the adhesions between it and the lips of the wound freed by gentle dissection with an iris repositor When the operator is sure that all adhesions have been broken down, and he can pull upon the iris within the eye in any direction in which he may pull the prolapse then it may be dealt with in the usual manner

If after removal of the prolapsed iris there is a tendency for the wound to gape then the gap must be covered by a conjunctival flap. The method of doing this will be explained under heading 3

2 **Cases in which the wound is at the corneo-scleral margin (limbus)**—These wounds are often very small and in civil life are seen after a perforation of the eye by a sharp-pointed implement such as a pin In all these cases a preliminary corneal incision must be made as the perforation is not large enough to admit an iris repositor and the pillars of the coloboma are very likely to be left adherent to the wound after the prolapse has been removed

These wounds usually need covering with conjunctiva either by means of a modified visor flap or in the less difficult cases by undermining the conjunctiva above and below the perforation and drawing the edges of the freed conjunctiva together by a mattress suture

3 **Cases in which the wound of the cornea extends beyond the limbus, thus involving both cornea and sclera**—Here there is a wound of the cornea limbus and sclera involving also the superjacent conjunctiva It is important to disclose the exact extent of the scleral wound which is obscured by the cut conjunctiva which rapidly becomes adherent to the sclera Furthermore the incision in the conjunctiva may be smaller than that in the sclera The first step then is to extend with scissors the conjunctival incision and dissect the cut edges from the sclera beneath If now a suture is passed through the conjunctiva on each side of the wound it may be retracted by the weight of a small artery forceps attached to each suture (Fig 818) In this way a beautiful exposure of the wound of the sclera and the prolapsed uvea results The prolapse is now dealt with in the manner previously described but it may not be possible to remove it with one snip of the scissors

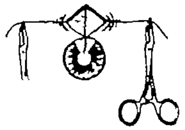

Fig 818
Method of exposing a corneo-scleral wound during the removal of prolapsed uvea

All scleral wounds must be completely covered with conjunctiva and this may be done with U shaped sutures passed a little distance from the edge of the conjunctival wound Even when the scleral wound gapes this procedure sufficiently braces it up and in no circumstances should the surgeon be tempted to try and pass sutures through the sclera which is extremely tough so that if an attempt (which is not necessary) be made it will certainly lead to the squeezing of vitreous from the eye

There is a type of wound which passes across the eye involving the cornea

and the limbus and sclera on each side of the corneal wound. Such cases are not often met with that admit an attempt at conservative treatment, and when an attempt is possible the wound in the cornea will be a little way from the limbus. Such wounds are usually seen in the lower part of the cornea, and after removal of the prolapsed uvea a gaping wound remains, and the disposition of parts is such that the lips of the wound cannot possibly come into apposition. Such wounds must be covered with conjunctiva in such a way that the lips of the wounds are brought together (Fig. 819).

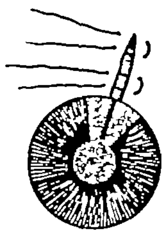

FIG. 819

Method of covering a scleral wound by suturing the conjunctiva over it by means of mattress sutures.

THE VISOR-FLAP OF CONJUNCTIVA.—The visor-flap of conjunctiva, or some modification of it, is most useful (Figs. 820 and 821) and can be used in all cases in which it is necessary to cover a gap in the cornea. It is formed by detaching the conjunctiva at the corneo-scleral margin for about half its extent. The conjunctiva is generously undermined, so that by taking the

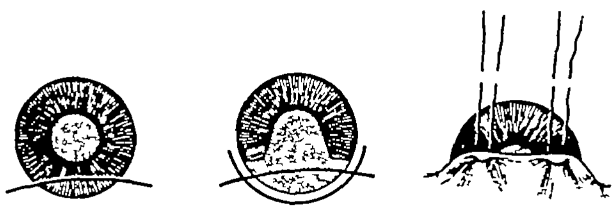

FIG. 820

Steps in the formation of a visor-flap to cover an extensive corneal incision. The flap is sutured to the conjunctiva just outside the limbus, opposite the corneal wound. When the sutures are tied the cornea is completely covered by conjunctiva.

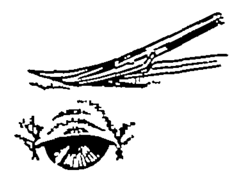

FIG. 821

Shows the manner in which a visor-flap may be converted into a band of conjunctiva covering a central wound of the cornea.

edge of the conjunctiva in two forceps it can completely bury the cornea without tension. Two mattress sutures are passed near the edge of the cut conjunctiva, which is drawn across the cornea and sutured to the conjunctiva near the opposite limbus. These sutures should be passed at the junction of the middle and outer thirds of the edge of the cut conjunctiva. Such sutures hold from five to seven days, and when they have become loose the conjunctiva will be firmly adherent to the site of the injury.

ANTERIOR SYNECHIA BETWEEN THE IRIS AND CORNEAL WOUND.—If iris is involved in a perforation of the cornea it is usually prolapsed, but cases occasionally occur in which the iris is slightly engaged in the corneal wound, so that no iris presents on the anterior surface of the cornea that can be seized with forceps. When such an injury is recent a short incision, 3 mm. in length, is made in the cornea 3 mm. within the limbus in a convenient place or as nearly opposite the perforating wound as can be arranged, and through this an iris repositor may be inserted and the iris detached.

If, however, the synechia has become consolidated the adhesion may be divided with the help of Lang's twin knives. These are essentially sharp and blunt tenotomes of such dimensions that the incision made by the sharp pointed knife will just admit the blunt-pointed knife. This blunt pointed knife has been modified by Gibbs with a curved cutting edge which prevents the synechia from slipping off the edge of the knife.

When using the twin knives, the eye is fixed with forceps by seizing the conjunctiva as near the limbus as practicable in the quadrant of the eye in which the corneal wound is situated. An incision in the opposite quadrant of the cornea is made with the sharp knife—which is withdrawn without loss of aqueous. This is essential, especially when there is an uninjured crystalline lens in the eye

The sharp knife having been withdrawn, the curved blunt pointed knife is introduced and by a sweeping movement the synechia is divided.

It is not always possible to divide synechiæ by reason of their situation. If they occur in the upper or inner part of the cornea the dividing knife may be inserted in the lower or outer part of the cornea, but if the synechia is in the lower or at the outer part, the prominence of the forehead and nose prevent the use of the dividing knife

It is important, if possible to divide anterior synechiæ not only because they cause irritation of the eye but also because they may later on lead to glaucoma. If a synechia cannot be divided by these means, either because of its toughness or situation, it may be subsequently divided with a Graefe knife or an iridectomy may be performed on each side of the synechia, thus freeing it.

PERFORATING INJURY OF THE CRYSTALLINE LENS

Whereas a variety of injuries such as post-cortical opacity and partial and total dislocation may occur to the lens by blows with blunt objects the injury produced by a sharp instrument has relation to traumatic cataract and its various complications

When the capsule of the lens is opened by a sharp instrument the aqueous obtains access to the lens fibres which become opaque and swollen If the lens capsule becomes incarcerated in a corneal wound it must be dealt with on similar principles to those laid down for prolapsed iris and anterior synechia of iris If the capsule is prolapsed it must be cut off but owing to the absence of the elasticity seen in the iris there is no tendency for the capsule to withdraw after tension has been placed on it by pulling on it with forceps consequently we meet with capsular synechia of the cornea more often than iris synechia Such synechia should be divided by Lang s knives since they are likely to cause iridocyclitis and glaucoma There is not the same difficulty in dividing capsular synechiæ as we are not dealing with an eye with an intact crystalline lens within it The main complication of traumatic cataract is glaucoma Raised tension is produced either by masses of swollen lens blocking the pupil or particles of opaque lens material blocking the angle of the anterior chamber It is therefore essential in all cases of traumatic cataract to keep the pupil widely dilated so as to allow plenty of room for the increasingly swelling lens fibres If in spite of the dilatation of the pupil the tension remains raised then the lens material must be removed which necessarily involves an incision in the eye

When undertaking such an operation care must be taken to decide whether the injury which opened the anterior capsule also perforated the posterior capsule because if an incision be made into the eye to remove lens matter in the presence of a tear of the posterior capsule vitreous is bound to escape consequently in such cases an operation to remove lens material should be avoided if possible

If however glaucoma results from the presence of the swollen lens matter in the anterior chamber then an operation will have to be undertaken to remove it

In young people that is under twenty-eight years of age a linear extraction may be undertaken This is performed as follows *After* a facial nerve block and a retrobulbar injection of novocain and the insertion of a superior rectus suture after paralysing the muscle with an *injection* of 5 to 10 minims of a 2 per cent solution of novocain an incision with a broad straight keratome is made in the upper part of the cornea 3 mm inside the *limbus* This site is chosen because in the event of a capsular

synechia, it may be divided with the twin knives. The soft lens matter is then washed out with a stream of normal saline solution at 100° F. Every effort should be made to avoid a capsular synechia or a prolapse of the iris. Prolapse of the iris is unlikely if the corneal incision be made in the situation advised. Subsequent treatment consists in keeping the pupil fully dilated. If the posterior capsule of the lens is intact a posterior capsulotomy will be needed at a later date.

If a traumatic cataract has occurred in a patient over twenty-eight years of age, then the ordinary cataract extraction with incision at the corneo-scleral margin will be necessary, and there are advantages in operating both in the case of young and older patients before glaucoma has arisen. The reason for the incision at the corneo-scleral margin is that a corneal incision with a keratome is not large enough to allow the expulsion of the nucleus of the lens of the older patient.

PERFORATING WOUNDS WITH RETENTION OF A FOREIGN BODY

The foregoing description has dealt with cases in which the instrument of perforation has been withdrawn from the eye after producing a perforation of the coats of the eye, complicated it may be by a prolapse of uvea or lens capsule. It now remains to deal with cases in which the perforating agent has remained within the eye, so that not only has a perforating wound to be treated, with or without a prolapse, but also the retained foreign body.

In civil life the retained foreign body, apart from gunshot wounds, is most commonly a piece of steel, as such cases nearly always arise during the use of a hammer and chisel, or whilst striking an iron or steel object. It is seldom that a portion of the material upon which a hammer and chisel is being used pierces the coats of the eyeball. During the operation of chipping with a hammer and chisel, the faces of the hammer and chisel become heated, and as it is from these surfaces that the foreign body arises they are to a certain extent sterilized, and thus a certain number of cases of intra-ocular foreign body are not grossly infected. If, however, the foreign body has arisen during work upon the roadway the fragment is often very dirty, so that suppuration is common and infection with gas-producing organisms is seen, with very rapid panophthalmitis and danger to the life of the patient.

Foreign bodies that enter the eye in warfare are of several varieties, and the treatment thereof depends upon whether they are magnetic or not. In civil life nearly all intra-ocular foreign bodies are magnetic, and most of our description of dealing with such cases will be a consideration of the use of electro-magnets in their removal. Foreign bodies may arise from portions of exploding shells, particles of bullet casing, pieces of detonators, grains of quartz from the ground, or small pieces of cordite. Shell and bullet casing particles are magnetic, pieces of detonators, which are of copper, and particles of quartz and cordite, are non-magnetic. Thus, although *magnetic* foreign bodies may be removable, unless non-magnetic foreign bodies are in the anterior chamber or, as rarely happens, visible with the ophthalmoscope, then removal is either impossible or accompanied by great difficulty and risk. The retention of an iron or copper particle

within the eye nearly always leads to a gradual deterioration of the eye so that it gradually loses its power of vision becomes blind and painful and subsequently has to be removed

Siderosis bulbi—If a piece of iron remains within the eye certain well known changes clinical and pathological take place It may happen that a retained foreign body is unsuspected especially if not accompanied by a prolapse so that if the crystalline lens be intact the patient does not appreciate that a serious injury has been sustained Such an eye is liable to recurring attacks of inflammation so that in a given case in which the history is that a perforating injury has possibly been sustained recurring attacks of iridocyclitis should immediately raise the suspicion that there is a piece of metal within the eye

Later characteristic changes in the appearance of the eye are seen a rustiness in colour of the iris which loses its lustre and pattern, a deposit of brown pigment immediately under the anterior lens capsule, often in lines radiating from the pupillary area (which often remains unaffected, especially in the early stages) so that the size of the deposits increase as we pass from the pupillary area towards the periphery of the lens. These changes are associated with vitreous opacity and retinal degeneration and a gradual deterioration of sight, ending in increased intra-ocular pressure so that the eye becomes blind and painful and needs excision. A slit-lamp examination will reveal a rusty staining of the cornea, opacities in the aqueous, and will make more obvious the changes in the iris. In the lens the situation of the discoloration, which consists of particles of iron rust in the epithelium of the lens, is easily localized and the early loss of the bands of discontinuity observed. The vitreous shows a characteristic appearance; there is pigmentation of the vitreous framework and two kinds of opacities: small, red, punctate opacities and white opacities of varying size the largest of which take the form of brilliant discs to which are attached some of the small red opacities already mentioned.

If a *particle of copper* be retained within the eye there may be an early non-septic purulent degeneration needing excision, but if the particle of copper be tolerated for a length of time a sequel of characteristic changes is seen After several months the cornea becomes impregnated with copper The site of the discoloration is in Descemet s membrane, and it begins exactly at the limbus, where it is most intense It gradually passes towards the middle of the cornea. It is greenish yellow in colour and may begin either above or below and form a continuous ring, thicker above than laterally It is curiously similar to the ring of Fleischer seen in hepato-lenticular degeneration (Kinnier Wilson s disease). Changes in the lens are also seen. There occurs an extremely shallow opacity situated in a layer immediately subjacent to the anterior capsule, grey blue or grey green in colour and taking on the form of a sunflower The anterior axial parts of the lens remain relatively unaffected, and this less affected part is contained within a ring which shows the minimum of opacification, and from which a certain number of slender opacities radiate towards the periphery The opacity shows an extremely bright polychromatic lustre which is often visible in ordinary daylight. No portion of the design of the sutures or fibres is seen and the rest of the lens is quite normal. The *framework* of the *vitreous* is composed of bundles and pseudo-membranes of a grey-green colour In some places the meshes are full of fine dust of the same colour; some opacities have a red metallic lustre and in other cases the opacities are partly red and partly white.

Particles of quartz, cordite or an eyelash (unless the follicle be included) may remain in the eye indefinitely without causing trouble and, unless visible in the anterior chamber and easily reached, are best left alone in view of the difficulty and danger involved in their removal. Particles of glass, as from a spectacle lens, are particularly difficult to deal with. They may be seen quite well in the anterior chamber with a slit lamp, but upon an attempt at their removal the incision in the cornea may so alter the optical conditions that the piece of glass is lost to view and, even when seen sufficiently well to be seized, may crumble so that only a portion may be removed, leaving smaller fragments within the eye with which it is impossible to deal. These cases in which a particle of glass in the anterior chamber is in contact with the cornea lead to recurring attacks of inflammation of longer and longer duration, which produce an increasing opacity of the part of the cornea involved. During an attack of inflammation it is quite impossible to remove the foreign body owing to its being obscured, and when the eye has settled, knowing the difficulties that will be encountered in an attempted removal, there is a tendency to leave it alone, a procedure in which the patient, who has good vision in the eye, usually concurs. In this way these eyes after a series of years become more and more of a nuisance so that they frequently end in excision.

THE DIAGNOSIS OF A RETAINED FOREIGN BODY

The history of the case is most important in giving a clue as to the possibility that a perforating wound has been caused by a foreign body

as well as the type of foreign body likely to be encountered. In civil life the foreign body is usually small and oat-shaped, weighing but a few grains, whereas in warfare the particle may be any shape and often much larger, rendering the damage it has done during entry of the eye much greater, as well as increasing the difficulty in its removal. A small perforating wound, especially if accompanied by a perforation of iris and lens *unaccompanied* by a prolapse of uvea, is very suggestive of a retained foreign body. It means that a tiny fragment has perforated the coats of the eye and that no aqueous has escaped. It is during the escape of aqueous through a perforation that the iris is liable to be washed out of the eye. We have insisted that in all cases of perforating injury of the eye the pupil should be *fully* dilated and an ophthalmoscopic examination carried out, and in any case of doubt a stereoscopic X-ray photograph taken. X-ray photography is not always necessary, and should not be insisted upon if it will cause any considerable delay in dealing surgically with the injured eye. An electro-magnet used in the extraction of a foreign body is also of diagnostic value, at any rate in the case of a magnetic intra-ocular foreign body. The diagnosis of the presence of a non-magnetic foreign body in the vitreous is usually only of value for prognosis.

Panophthalmitis—This is liable to follow a perforating wound that has involved either or both the lens and vitreous. If a foreign body has come to rest in the anterior chamber, infection is usually overcome by suitable remedies, but the lens and vitreous are such suitable media for the growth of organisms at an optimum temperature that infection almost always calls for a removal of the eye. The wound of entry may or may not show signs of infection, and suspicion may first be aroused by increasing congestion of the superficial vessels of the eye, discoloration of the iris with possibly exudation into the anterior chamber, and a yellow discoloration of the injured lens or cloudiness in the vitreous. A significant sign of infection of the vitreous is rapid loss of visual acuity and of the correct projection of light shone into the eye with a mirror. Later signs are chemosis, proptosis, and restricted movement of the eye, due to orbital cellulitis or orbital œdema.

If it is decided to remove the eye, a choice of methods is available. If the eye can be removed without rupture and extrusion of its contents, then excision is the better plan. If, however, it is likely that the eye will burst during excision, the attempt should be abandoned. When excising an eye, the subject of panophthalmitis, it will be found that the muscles and other contents of the orbit are very much swollen and friable, and it will need quite an amount of dissection to free the globe. If, after this extensive dissection, the orbit becomes flooded with infected ocular contents, there will be gross soiling of orbital tissues which may lead to spread of infection to the meninges with fatal results. It is better to eviscerate the eye and then remove the sclera without opening the sheath of the optic nerves. This operation (Lister's frill operation) is performed as follows. General anæsthesia may be necessary, and evipan is both convenient and suitable.

The cornea is removed with scissors, if necessary, after piercing the corneo-scleral margin with a sharp-pointed knife. The cut edge of the sclera is then seized with three Spencer-Wells artery forceps for about 3 mm., and

the contents of the eye scooped out and the sclera then carefully wiped out with gauze so as to make certain that all uveal tissue has been removed. The sclera is then packed with ribbon gauze and the conjunctiva and muscles carefully stripped from the sclera When the sclera has been stripped quite clean the packing is removed and the sclera cut across just anterior to the posterior pole of the eye so that the optic nerve sheath is not opened. If the greater part of the sclera is not removed it will gradually slough and will have to be removed piecemeal over a period of several weeks during which a dirty discharging condition of the orbit persists In no circumstances is a packing to be inserted into the orbit

RUPTURED GLOBE

A perforating wound which has caused a ruptured globe will not allow an ordinary excision to be performed The eye in these circumstances has lost most of its fluid contents and the sclera is split into a series of petal like portions An operation very similar to that performed after an evisceration of the globe in panophthalmitis is performed the strip of sclera being seized with several artery forceps the uvea scooped out the sclera wiped dry and after packing freed from the orbital contents A scleral frill operation is then performed It is essential to preserve all conjunctiva in order to obtain a roomy socket to accommodate an artificial eye

TECHNIQUE OF THE REMOVAL OF A MAGNETIC INTRA-OCULAR FOREIGN BODY

Although two established methods for the removal of an intra-ocular magnetic foreign body are in use it is almost always necessary to use what is called the anterior route in war injuries The posterior route operation consists in the use of a small hand electro-magnet introduced through the sclera after a careful X ray localization In war injuries we can never be certain that an intra-ocular foreign body is magnetic, and so it would follow that a large number of eyes would be incised and an electro magnet point inserted unnecessarily and in vain In consequence the procedure adopted and recommended is to draw the foreign body into the anterior chamber by means of a large electro magnet whence it may be removed while still observed by means of a hand electro-magnet It will be granted that it is both easier and safer to remove a foreign body whose situation is exactly known and that can be seen during all stages of the operation Now the easiest foreign body to remove is one that has come to rest in the anterior chamber and which is not entangled in any ocular contents The use of the giant magnet is to convert every case of intra-ocular foreign body into one in which the foreign body lies free in the anterior chamber

Except in rare instances the wound of entry made by the foreign body is disregarded and in those cases in which the wound is large the eye will probably have been so much injured that there is no possibility of saving it The plan that will be described and recommended, then, is to draw the foreign body through the pupil into the anterior chamber with the giant magnet and then through a planned incision remove it through the cornea Any prolapse of uvea the result of the perforating injury is dealt with after the foreign body has been removed

Equipment—Two giant magnets are in common use in England · that devised by Professor Haab and the other by Professor Mellinger The Haab magnet is a very familiar one, and consists of a unipolar electro-magnet with a moderately short terminal, used without a rheostat and controlled by means of a pedal The great advantage is that immediately the patient experiences pain he can withdraw his head. This is, as it were, a safety-valve, because when the patient withdraws his head he removes his eye from the influence of the magnet and so prevents the foreign body, when it comes into contact with the iris (which causes pain), from becoming entangled With the Mellinger magnet as usually used, the patient is recumbent and the coil encircles his head The magnetized core is held in the surgeon's hand in the middle of the coil over the patient's eye If, now, the pull of the magnet draws the foreign body into contact with the iris, the patient cannot withdraw his head, and so the particle may become entangled in the iris from which it may be extremely difficult or impossible to disengage it Furthermore, it is much more likely to injure the lens which may not have been pierced by the original wound The giant magnet is used in company with a hand electro-magnet weighing about half a pound and actuated by a four-cell accumulator It is essential that the current be controlled with a foot-switch This is preferable to incorporating a Morse key in the circuit, as this has to be managed by an assistant, and it is preferable to have the magnet completely under the surgeon's control It is not advisable to use a permanent magnet since, if after the foreign body has been attracted by it, it becomes entangled in the iris, the foreign body cannot be released and will in consequence drag the complete iris from the eye, as the magnet is used after incision of the cornea The usual means of anæsthetizing the eye are used, so that a syringe and a 4 per cent solution of novocain, a 2 cm hypodermic needle, and a 3 5 cm fine hypodermic needle are necessary A corneal incision is made with a straight keratome 10 mm from base to apex and 8 mm inside at its base A lid speculum, fixation forceps, iris forceps, de Wecker's scissors and an iris repositor complete the outfit An undine filled with normal saline solution at 100° F with 3 ft of tubing and a flattened silver nozzle is a useful adjunct Good illumination is essential, and one of the operating lamps that have been introduced in recent years much simplifies the operation The illumination of the eye may not be very easy and needs some experience by the person who holds the lamp, a point very frequently neglected

Preparation of the patient for operation—The pupil must be *fully dilated*, if necessary, by means of a subconjunctival injection of "mydricaine" Local anæsthesia is obtained by means of cocaine drops (4 per cent) or pantocaine (1 per cent) applied every three minutes for fifteen minutes These drops may be usefully combined with the application of a few drops of a solution of adrenalin (1 1,000)

WHEN A CORNEAL FOREIGN BODY IS PARTLY IN THE ANTERIOR CHAMBER

The danger in dealing with these cases is that during an attempt to remove the foreign body the anterior chamber may be lost, the foreign body will

come into contact with the lens capsule and if this be injured a traumatic cataract will result Also any further attempt to remove the foreign body must be abandoned until the anterior chamber has re formed Two procedures are open to the surgeon If after a careful examination with the slit lamp to decide the exact depth of the foreign body has been carried out a considerable amount of the foreign body is projecting behind the cornea it may be pushed into the anterior chamber from which after the aqueous has sufficiently re-formed it may be removed by the small magnet in the manner described in dealing with a magnetic foreign body

FIG 822

In this case the foreign body has perforated the cornea and so lies partially in the cornea, and partly in the anterior chamber The bent knife is inserted behind the foreign body so as to prevent its damaging the lens during an attempt at its removal.

The other procedure is to perforate the cornea with a bent Taylor s knife drive it across the anterior chamber behind the foreign body fixing the point of the knife in the cornea upon the opposite side The knife is held in position behind the foreign body so that the lens is protected during the subsequent manœuvres to remove the splinter in the cornea (Fig 822)

FIG 823

Method of using an iris hook to remove a non magnetic foreign body from the anterior chamber and the incision that may be necessary so as to use a forceps for the same purpose

Non-magnetic foreign bodies in the anterior chamber —These must be removed either by forceps or iris hook and the manipulation of such instruments in the anterior chamber with an intact crystalline lens is of extreme danger It has been usual when a foreign body is lying on the iris (often in the lower part of the anterior chamber) to make an incision at the limbus at the site of the foreign body and then introducing curved or straight iris forceps to try to seize the foreign body and to remove it (Fig 823) This often fails and then an iridectomy is made in the hope of including the foreign body in the piece of iris removed Another plan is to make a small incision in the cornea just within the limbus to one side of the foreign body and then to try to remove it by means of an iris hook

An eyelash in the anterior chamber may be removed with toothless forceps through a similar corneal incision if it be disentangled and gently coaxed over the iris by a stream of saline solution through a silver nozzle

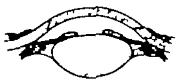

FIG 824

Shows on the right hand side the usual incision by a keratome or Graefe knife in such operations as iridectomy or cataract extraction. It illustrates the difficulty that may be encountered if such an incision be made in an attempt to remove a non magnetic foreign body near the angle of the anterior chamber by means of a forceps. On the left hand side is the incision recommended for use with forceps to remove a non magnetic foreign body lying in the iris.

TECHNIQUE OF THE HAAB MAGNET

1 **Position of the patient**—(*a*) IF THE PATIENT CAN SIT UP—The patient is seated on a chair of ordinary height with a back. The height of the patient is regulated with cushions until the eye is on a level slightly above that of the magnet point The chair is drawn up as closely as possible to the

magnet, the patient folds his arms and rests the forearms on the shelf attached to the magnet pillar This movement must be regulated by the surgeon, so as to avoid injury to the eye by bumping it against the magnet

(*b*) IF INJURIES OR GENERAL CONDITION PREVENT THE PATIENT SITTING UP—This contingency is extremely unlikely in civil life, but has been met with frequently in war casualties

The stretcher, with the patient on it, is placed on the operating table, and the magnet is brought as close as possible to the head of the table, on the left side The head end of the stretcher is then moved laterally towards the magnet so that one of the runners rests upon the arm shelf attached to the magnet pillar The head of the patient is elevated by placing pillows under his head and shoulders until he is in a semi-recumbent position, with the level of the injured eye a little above that of the magnet point The head is then turned to face the magnet

We always work with the magnet on the left side of the patient, irrespective of which eye is injured

2 POSITION OF THE SURGEON—The surgeon stands on the right side of the seated patient, with his left foot and left shoulder somewhat behind the patient and his right foot and right shoulder slightly in advance He rests the back of the patient's head in the hollow formed by his flexed elbow, supporting the head chiefly with the upper arm This restrains any sudden movement of the head backwards, and enables the surgeon to bring the head of a nervous patient forward without undue effort

(*a*) *Surgeon's hands*—The palm of the left hand is placed on the forehead of the patient above the injured eye the forefinger retracts the upper eyelid and retains it in position by pressure against the upper margin of the orbit This also, by lifting the eyebrow, controls the most powerful part of the orbicularis and corrugator supercilii muscles The other fingers should remain outstretched and placed on the bevelled core of the magnet, so as to regulate the distance of the eye from the magnet and to prevent pressure of the magnet point upon the globe The thumb of the left hand remains on the forehead of the patient

The fingers of the right hand grasp the lower jaw below, while the outstretched thumb retracts the lower eyelid, pressing against the lower margin of the orbit The distal joint of the thumb is slightly flexed, and the projection of this joint may be used to regulate further the distance of the eye from the magnet, by contact with the bevelled core

(*b*) *Position of surgeon's head*—The head should be inclined to his right shoulder, so that he views the patient's eye from the front as well as laterally and at the same time does not obstruct the light from the operating lamp From this position any movement of the iris, and often of the foreign body advancing through the vitreous, can be observed

3 POSITION OF OPERATING LAMP—The lamp is placed behind the magnet and on the patient's right side on the level of the magnet point The beam of light is directed on the injured eye parallel to the bevel of the magnet core The distance is regulated so as to get the greatest concentration of light The question of illumination is important, since a good light enables the surgeon to detect at once any movement of the iris

4. MANIPULATION OF THE PATIENT'S HEAD—The patient's head should

not be advanced erect and facing directly forward to the magnet if this be done it will be found that the nose to an extent dependent on its size will come into contact with the bevelled core and will prevent the head being advanced to the required position Instead the chin should be elevated the head inclined slightly towards the same shoulder as the injured eye and rotated towards the opposite shoulder Thus in the case of a right eye the head is tilted back, inclined to the right shoulder and rotated towards the left The patient is instructed to keep both eyes widely open to look at the magnet point and to allow the surgeon to move his head freely in any direction. The head is then advanced until the magnet point comes into contact with the cornea just above its centre

5 OPERATION UPON PATIENT LYING DOWN—In the cases in which the general condition or injuries of the patient necessitate the recumbent position or in which the operation with the Haab proves to be so painful that a general anæsthetic is required for its completion the surgeon stands above the patient s head The upper eyelid is retracted with the forefinger of the left hand and the lower eyelid with the forefinger or thumb of the right hand the head and face being grasped between the two palms

If the patient is under an anæsthetic and the whole weight of the head has to be supported it is convenient to insert Clarke s wire speculum between the eyelids The pedal of the magnet has to be worked by the assistant at the direction of the operator

The operating lamp in these circumstances is adjusted so that the projector is over the patient s abdomen and the beam of light shines down on to the patient s face It requires some care to secure the best illumination

The full strength of the current is switched on by depressing the pedal It is important that at this moment the magnet point should actually be in contact with the cornea slightly above its centre It is surprising how much power is lost if there is a space of only a few millimetres between the cornea and the point of the magnet

The reason for this relative position of eye and magnet will be readily understood when we consider the forces acting on the foreign body namely the vertical pull of gravity and the horizontal pull of the magnet The foreign body will follow the resultant of these two forces and travel obliquely downwards instead of horizontally forwards This is partly the reason why most foreign bodies are present behind the lower part of the iris also X ray localizations show that in the majority of cases foreign bodies after penetrating the globe sink to the lower part of the vitreous chamber

The object of the sudden application of the full current is to disengage the foreign body from its bed (if it is resting on the retina) and to make it pass forward through the vitreous to the posterior surface of the lens as nearly as possible in the horizontal plane

Foreign bodies may sometimes be seen through the vitreous until they come into contact with the posterior surface of the lens, and then slipping round the edge of the lens, suddenly appear quite free in the anterior chamber This is the ideal result

If the force be gradually applied either by the use of a rheostat or by starting with the eye at some distance and gradually advancing the head until the cornea comes into contact with the magnet point three dangers

will be incurred, namely the foreign body may be (1) dragged along the retina, (2) forced into the ciliary body, or (3) become entangled in the root of the iris Usually the foreign body shows its presence in the posterior chamber by pushing the iris before it.

When the foreign body presses on the iris, the patient experiences pain, and may state that he feels as if something were dragging on the eye It is most important to notice the exact moment and position at which the bulging of the iris occurs the moment, because the current must be cut off at once, to avoid entangling the foreign body in the substance of the iris, and the position, as this determines the subsequent manœuvres adopted to bring the foreign body through the pupil into the anterior chamber

A very common position at which the foreign body presents itself is below In such a case, after shutting off the current, the patient is told to look down, the head is tilted slightly forward and the magnet point applied to the upper margin of the cornea The current is then switched on again, and the foreign body slips forward through the pupil to the posterior surface of the cornea The current is maintained, the head slightly withdrawn and the patient told to look upwards until the magnet point is at the lowest part of the limbus

The foreign body is thus drawn into the bottom of the angle of the anterior chamber, the most suitable position from which to remove it with the small magnet

The above is a description of the simplest case At any stage in the operation difficulties may be encountered

1 **Delay in the passage of the foreign body through the vitreous chamber**—Delay is most common in those cases in which the foreign body has been in the eye two or more days before the attempt at removal, and in which, consequently, it may be more or less fixed by exudate Foreign bodies not infrequently appear in the anterior chamber coated with the exudate that has formed round them

Almost always when a magnetic foreign body is present in the eye, the patient experiences some sensation of dragging from the first moment of application of the magnet Even if no dragging sensation be felt when the magnet is applied to the centre of the cornea, a very small magnetic foreign body may be present, and an attempt should be made to elicit the sensation by applying the point of the magnet to the sclera as far back as possible, above, below and laterally If the sensation of dragging be produced, efforts to bring forward the foreign body must be persisted in for a considerable time It is in these cases that the method employed by Haab proves most useful, that of applying the force of the magnet in a series of jerks The magnet is applied to the centre of the cornea, and the current rapidly switched on and off with the pedal, alternating this with a series of long pulls

We have in some cases obtained ultimate success by persisting in this method for five or more minutes It may be desirable to interrupt the attempt for some hours if the magnet becomes overheated, in order to allow it to cool

In obstinate cases the foreign body may sometimes be loosened by applying the magnet to various points on the sclera, so as to pull the foreign body in various directions, and so loosen it In this way also a greater force may be exerted by placing the point closer to the foreign body This manœuvre is similar to the loosening of a stake driven into the ground by lateral movements before removing it by a straight pull

It may be noted that delay in the vitreous is much more likely to occur in those cases in which there is some element of infection

The presence of infection in the eye frequently causes the formation of bands in the vitreous which are attached to the foreign body It will then be found that the foreign body can be brought forward with the Haab magnet, but on breaking the current it is drawn back again into the vitreous In these cases persistent attempts must be made to break the bands, or at all events to stretch them as much as possible, before proceeding to the second stage of removal with the small magnet This should be done by varying the position of the eye and the patient's head, so as to cause the greatest possible amount of tension to be put on the bands when the magnet is applied

2 **Entanglement of the foreign body in the iris**—*When a foreign body is drawn forward, it frequently becomes more or less entangled in the iris* This shows itself by movement of the affected part of the iris towards the magnet point Such cases require the greatest amount of care in

manipulation It is imperative to disentangle the foreign body and to bring it forward into the anterior chamber since if this is not done any attempt to remove the foreign body with the small *magnet is almost certain to end in disaster* It is improper to try to pull the foreign body through the iris; this will only impact it in the tissue

The foreign body having shown its presence in the posterior chamber by bulging the iris forward, *the current must be cut off immediately* We will suppose again that the foreign body has presented below in the right eye The head of the patient is bent forward, the chin inclined to the left shoulder and the magnet point applied to the limbus up and out so that the line of its pull shall be as far as possible *in the plane of the iris*, with as little forward drag as possible The patient is at the same time told to look down and to the left. The current is then switched on, and after one or two attempts, the foreign body will probably be released and come forward. If this be not successful, it is generally possible *to detach the foreign body from the iris* by applying the magnet point still farther back on the sclera, so that the pull is actually behind the plane of the iris. Once the foreign body is detached it can easily be brought forward into the anterior chamber

Similar manœuvres may be adopted for foreign bodies presenting at other points, with an appropriate change of the relative positions of eye and magnet.

3. **The presence of a small corneal or corneo-scleral wound with prolapse of iris**—No attempt *must be made to remove the foreign body through such a wound*, or through any enlargement of that wound. The foreign body should be treated as indicated above and brought to rest as near the lower angle of the anterior chamber as possible The subsequent treatment of such a condition *will be described later*

4 **The presence of a very large corneal wound**—In these cases the presence of a large intra-ocular foreign body is indicated, and the chance of saving the eye is correspondingly slight. There is considerable danger that iris, ciliary body lens, or vitreous may be dragged out in an attempt at removal of the foreign body Any attempt with the Haab magnet must be begun very cautiously with the eye at some distance and the effect closely observed.

At the first sign of the foreign body presenting behind the cornea all further attempts with the Haab must cease, and the foreign body should be removed with the small magnet—as a rule through the corneal wound. The small magnet gives ample power and is under much better control.

5. **The presence of an unhealed scleral wound**—If the wound be *large*, the foreign body should be removed through this wound, with the same precautions as in the case of a large corneal wound, and the sclera be sutured. If the wound be *small* the foreign body should be removed by way of the anterior chamber as if no scleral wound existed. The wound in the sclera, made by a small foreign body never gives sufficient room for the withdrawal of the foreign body with the magnet, and consequently would have to be enlarged. Even were the hole sufficiently large the chances of the foreign body engaging accurately in it are extremely slight. But in any case the conjunctiva should be sutured carefully over the scleral wound after the foreign body has been removed.

THE TECHNIQUE OF THE SMALL MAGNET IN THE REMOVAL OF THE FOREIGN BODY FROM THE ANTERIOR CHAMBER

Having brought forward and deposited the foreign body in the lower angle of the anterior chamber the next step is its removal from the eye Unless the eye is white and quiet and the patient amenable it will be necessary to block the facial nerve and give a retrobulbar injection of novocain.

The patient is placed upon the operating table with the head supported by a cylindrical sandbag which is adjusted in a comfortable position in the nape of the neck.

After the eye has been anaesthetized, the conjunctival sac is gently irrigated with normal saline solution at a temperature of 100° F For this purpose the eyelids are everted and special attention is paid to the lid margins and to both canthi as well as to the fornices

The speculum is *inserted and a firm grasp of the conjunctiva* and subconjunctival tissue is taken at or slightly below the horizontal meridian of the cornea just outside the limbus The eye is rotated well downwards

The corneal section is now made directly above beginning at a point 3 mm below the limbus that is about half way between the limbus and the centre of the cornea The point of the blade is directed straight towards the foreign body and the section is completed by an onward thrust without lateral movement A section made in this way will be of a valvular

description, and on withdrawal of the keratome the lips of the wound will come together and prevent the escape of aqueous

The size of the incision is determined by the dimensions of the foreign body, and it may be necessary to carry the point of the keratome down almost to the angle of the anterior chamber Allowance must be made for the fact that the opening on the deep surface of the cornea is smaller than that on the superficial surface

The keratome is withdrawn fairly rapidly, without any jerk, and precisely in the plane of its insertion At the same moment the grasp of the conjunctiva is released, it will be found that little or no aqueous is lost This end will be still more certainly attained if the weight of the speculum be taken off the eye by the assistant Without loss of time the small magnet is taken, and the point of the terminal is directed outside the cornea and immediately over the foreign body In this way the foreign body is attracted to the posterior surface of the cornea by bringing the terminal upwards, still close to the cornea, the foreign body is drawn along the posterior surface and into the corneal section The terminal is depressed on to the wound and the foreign body thus withdrawn During the whole manœuvre, if possible, the eye must not be touched with fixation forceps, or the aqueous will probably be lost Any tendency of the iris to prolapse after the foreign body has been removed is overcome by manipulation with the iris repositor

In a certain number of cases, in spite of all care, the aqueous humour is completely lost It is then impossible to withdraw the foreign body in the manner indicated above

Two methods of dealing with the case are now open, the first of which is to fill the anterior chamber with normal saline solution and then to remove the foreign body as before

The second method is carried out as follows The eye is firmly seized with the fixation forceps in the horizontal meridian and rotated well downwards The magnetic terminal, with the current off, is introduced into the corneal section and passed straight down into the angle of the anterior chamber until it comes into actual contact with the foreign body The current is then switched on and the foreign body gently removed Any tendency of the foreign body to hitch on the lips of the wound may be overcome by rotating the flattened magnet point so as to separate the lips of the incision It will sometimes be found that on passing the terminal down along the posterior surface of the cornea the lower pupillary border of the iris is pushed in front of it, and the magnet point cannot be brought into contact with the foreign body Any attempt at removal then will only entangle the foreign body in the iris The point must be insinuated in front of the iris by withdrawing it slightly and sweeping it laterally and downwards with a movement following the curve of the pupillary border If by chance the foreign body should become entangled in the iris, the current must be switched off and the terminal placed in a more favourable position before a fresh attempt is made, otherwise the iris will be torn away at its root

It is very unusual to meet with a prolapse of iris through the corneal section, and should the iris become attached to the corneal section its favourable position allows of its detachment by means of Lang's twin knives

The foregoing description applies to uncomplicated cases, various conditions may be present which make the operation more difficult

1 **Complications due to the nature of the wound caused by the entrance of the foreign body**—(*a*) Presence of a prolapse of iris—The procedure for removal of the foreign body is the same as that adopted in an uncomplicated case After the foreign body has been removed the prolapsed iris should be cut off in the usual way

On no account should the iridectomy be performed first, and then an attempt made to remove the foreign body through the site of the prolapse or an enlargement thereof If the wound extend past the limbus, it may be necessary to insert a conjunctival or scleral suture

It may be noted that a wound of the sclera may have to be treated in the same way, and a prolapse of vitreous cut off The presence of an unhealed wound makes the section more difficult, by reason of the lowered intra ocular tension

(*b*) The presence of a traumatic cataract—If the foreign body can be seen in the lens and the eye shows no signs of infection, operation for removal of the foreign body should be deferred until such time as the cataract is also ready for removal If, however, the lens be considerably broken

up and coming forward into the anterior chamber the foreign body should be brought forward with the Haab magnet and removed as described, and the operation completed by washing out as much soft lens matter as possible

If the eye be infected, operation should be undertaken at once and the anterior chamber thoroughly irrigated with normal saline solution at a temperature of 100° F

2. Complications due to infection of the eye—(a) PRESENCE OF VITREOUS BANDS—In the cases referred to under the *technique* of the Haab magnet where vitreous bands prevent the foreign body coming forward freely and the attempts with the Haab magnet have failed to free the foreign body entirely difficulty will be experienced with the small magnet Application of the point of the small magnet outside the cornea will be ineffectual; the terminal must be introduced into the anterior chamber and the end placed as near as possible to the spot where the foreign body presented. The current is then turned on and an attempt made to free the foreign body by gentle traction and lateral movements. It may be necessary to assist the magnet with some non magnetic instrument such as an iris repositor

(b) CASES WITH EXUDATE IN THE ANTERIOR CHAMBER OR HYPOPYON—The exudate which often forms a cast of the anterior chamber may come out with the foreign body and in default of this should be removed with iris forceps. After removal of the exudate a rather illusory impression of the condition of the eye is produced by the clearing of the iris and pupil, but the subsequent course of such cases frequently proves disappointing

If hypopyon be present it should be removed by freely irrigating the anterior chamber with normal saline solution

The operation in every case is completed by placing a piece of sterile (1 per cent) atropine ointment in the conjunctival sac and applying a pad and bandage

The after treatment of these cases is conducted on general lines, namely frequent hot bathing and the use of atropine ointment together with complete rest in bed.

3. Cases in which the use of the giant magnet has failed to draw the foreign body forward—Cases are occasionally met with in which the giant magnet *has failed* to draw the foreign body forward. If the media are clear the foreign body may be seen in the fundus and possibly it may be seen to move a little when the giant magnet is applied. Even when the media of the eye are not clear enough to see the foreign body the sensation of pain induced by the application of the giant magnet may make it certain that the foreign body is magnetic and therefore some other means must be adopted to bring about its removal.

If it has been proved that a magnetic foreign body is in the eye it must in the first instance be precisely localized, and modern apparatus in the hands of an expert gives very precise results. When this has been accomplished the conjunctiva in a convenient position is reflected, so that the hand magnet terminal may be introduced into the eye through a suitable incision and the foreign body removed possibly under the control of ophthalmoscopy There is a danger of a subsequent detachment of the retina after an incision has been made and therefore to avoid this, an area of diathermy coagulation of the choroid must be made at the site of the proposed incision. Weve (Fig 825) suggests that the incision be made with a diathermy knife and that the sclera be supported by sutures on each side of the proposed incision. He has had several encouraging results from such a procedure

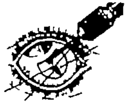

FIG 825

Illustrates Weve's method of using a diathermy knife for piercing the sclera previous to the removal of a foreign body in the vitreous or retina.

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SECTION XVIII

SURGICAL DISEASES ENCOUNTERED IN SUBTROPICAL COUNTRIES

CHAPTER LXXV

SUBTROPICAL SURGERY

AMŒBIC HEPATITIS

AMŒBIC infection of the liver by the portal vein is a common complication of amœbiasis. Hepatitis results and suppuration is liable to follow if the virulence of the infection overcomes the resistance of the patient. If an amœbic abscess develops superadded infection by other organisms is apt to occur.

Acute hepatitis is commonly ushered in by a rigor associated with abdominal pain, remittent fever and enlargement of the liver which is tender on palpation. The condition is of surgical importance in that suppuration is liable to supervene after a variable interval of only a few days to many months. In the majority of cases confirmatory evidence is obtained by the examination of the stools which are found to contain entamœba histolytica.

Amœbic hepatitis usually responds to a course of emetine combined with appropriate diet and nursing. Emetine is one of four alkaloids contained in ipecacuanha and is the only one which possesses definite therapeutic properties. The usual dose is 1 gr. daily injected intramuscularly for a period of twelve days. Asthenia, cardiac irregularity and mental depression may necessitate diminution of dosage or curtailment of the course. Emetine bismuth iodide (E.B.I.) is sometimes preferred to emetine and can be given by the mouth in doses up to 3 gr. a day for ten or twelve days. It should be contained in a hard gelatin capsule and given at night when the stomach is empty. Associated colitis is best treated by combined E.B.I. at night and Yatren (syn. Quinoxyl) retention enemata by day. After a preliminary wash out for which 2 per cent. sodium bicarbonate is used, 200 c.c. of 2½ per cent. Yatren is introduced into the bowel and this should be retained for a period of between four and eight hours.

Acute hepatitis must be distinguished from such conditions as malaria, acute cholecystitis, typhoid fever and basal pleurisy or pneumonia. Consideration of the history, clinical examination and blood tests all assist in forming an accurate diagnosis. If doubt exists as to whether suppuration has actually occurred and if symptoms are sufficiently severe to warrant such a procedure, needling of the liver, as described subsequently, should be undertaken. It is remarkable how some cases of hepatitis resolve after this minor operation, even though no pus is discovered. This phenomenon is perhaps analogous to the good results often obtained after laparotomy in cases of ascitic tuberculous peritonitis.

Hepatic abscess usually develops within a few weeks of an attack of

amœbic dysentery, but its presence should always be suspected when a patient, who has previously suffered from amœbic dysentery, presents himself with a vague pyrexial illness (Fig 826) The more common symptoms include asthenia, anorexia, wasting, sweating and pain, commonly referred to the right shoulder owing to irritation of the diaphragm The patient often exhibits a sallow or "muddy" complexion, and some degree of pyrexia is usually evident, but a curious feature is that the pulse rate is commonly relatively slow in proportion to the temperature Hepatic enlargement can usually be detected either downward, in which case the liver is palpable below the costal margin, laterally, as indicated by bulging of the lower ribs on the right side, or upwards In the latter case compression of the lung results in dullness on percussion, and diminished breath sounds on auscultation In any case pain is usually in evidence if the lower chest wall is subjected to bimanual compression

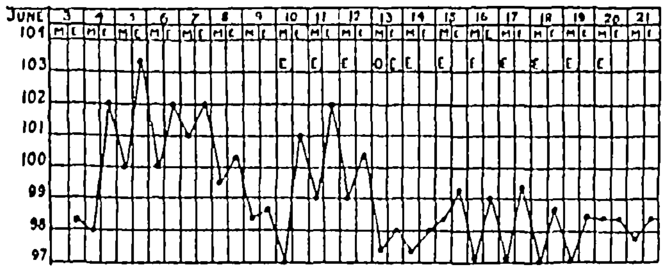

Fig 826

Typical chart of a patient suffering from an amœbic abscess

E, Emetine, 1 gr, O, Operation Quinine, 30 gr, was given on 7th and 8th June Blood film examined for malaria on 6th June, and blood culture for enteric group on 12th June, both gave negative results

A sympathetic pleural effusion is occasionally of sufficient size to allow of clinical recognition, or in some cases evidence of pleural irritation suggests some subphrenic inflammation

Blood examination often supplies valuable information, and a relative increase in the percentage of polymorphonuclear cells is of assistance in distinguishing between simple and suppurative hepatitis An illustration of the value of a differential cytological examination concerns a patient who was admitted to hospital with an enlarged and tender liver, slight fever and diarrhœa The total white cell count was 18,500 per c c, but only 60 per cent were polymorphonuclear A diagnosis of dysenteric hepatitis was made, and the condition subsided under a suitable diet and emetine injections

Radiographic examination is a valuable aid to diagnosis in doubtful cases (Fig 827) Three points are of assistance in confirming the presence of a liver abscess —

1 Increase in the size of the liver in an upward direction
2 Limitation of movement of the diaphragm, the normal $1\frac{1}{2}$ in excursion is reduced to $\frac{1}{2}$ in or less
3 The normal dome-shaped convexity is sometimes distorted by a bulge which represents a pointing abscess

Treatment—Amœbic hepatitis is the precursor of a liver abscess, and suppuration is doubtless prevented in many instances by the exhibition of emetine or E B I, together with confinement to bed and suitable diet

Suppuration is to be suspected if the temperature continues to oscillate,

and if hepatic enlargement persists Blood examination may support the suspicion that pus is present and as already mentioned an X ray is frequently diagnostic The final court of appeal is the aspirating needle

FIG 827

A liver abscess causing deformity and elevation of the right dome of the diaphragm. (*Dr Carmichael Low by the courtesy of Sir P Manson Bahr*)

A few days delay prior to aspiration during which period the patient is under treatment is beneficial providing that his condition is not deteriorating The emetine raises the resistance to infection and encourages localization of the pus Moreover hepatitis begins to resolve and the liver becomes less congested and friable and needling is therefore less liable to cause hæmorrhage or trauma to the organ

ASPIRATION of a liver abscess is best conducted under evipan or gas and oxygen anæsthesia[1] If the surgeon could be confident of reaching an abscess through one puncture then local anæsthesia would be ideal but commonly more than one puncture is necessary and frequent infiltrations of novocain are tedious and trying for the average patient Aspiration is sometimes the last resort in distinguishing between an empyoma and a subphrenic abscess In the latter case when pus is discovered the needle has of necessity penetrated the diaphragm the movements of which are conducted to the needle which consequently moves upwards and downwards with each respiratory excursion

Aspiration of a suspected liver abscess requires a large bore needle (No 9 bore) as the pus is usually thick and viscid especially if the abscess or abscesses are subacute rather than chronic or small in size In one case under the author's care pus was confidently expected and ten punctures failed to reveal an abscess although flakes of lymph were sucked into the syringe As the liver was also enlarged downwards a laparotomy was performed and two abscesses on the under surface of the liver were drained The patient died the following day and at necropsy it was found that there were four abscesses in the left lobe and thirteen in the right lobe The needle was of wide bore but pus in the abscesses was thick and gelatinous

[1] Operations in the tropics during the hot season are preferably performed as early in the day as convenient. Pre-operative atropine must not be given if high climatic temperature prevails, otherwise sweating is liable to be suspended. The writer has reported a case of heat stroke which occurred during an operation for hernia, in which a preliminary dose of atropine was inadvertently administered.

amœbic dysentery, but its presence should always be suspected when a patient, who has previously suffered from amœbic dysentery, presents himself with a vague pyrexial illness (Fig. 826). The more common symptoms include asthenia, anorexia, wasting, sweating and pain, commonly referred to the right shoulder owing to irritation of the diaphragm. The patient often exhibits a sallow or "muddy" complexion and some degree of pyrexia is usually evident but a curious feature is that the pulse rate is commonly relatively slow in proportion to the temperature. Hepatic enlargement can usually be detected either downward in which case the liver is palpable below the costal margin laterally, as indicated by bulging of the lower ribs on the right side or upwards. In the latter case compression of the lung results in dullness on percussion, and diminished breath sounds on auscultation In any case pain is usually in evidence if the lower chest wall is subjected to bimanual compression.

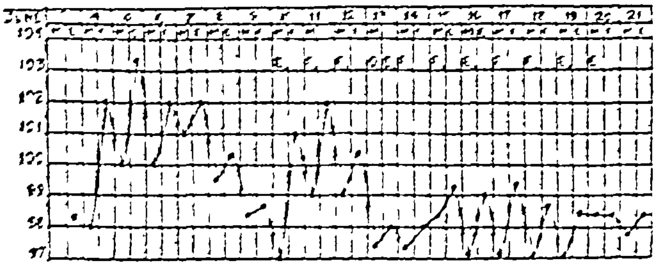

Fig. 826

Typical chart of a patient suffering from an amœbic abscess. E, Emetine, 1 gr.; O, Operation. Quinine, 30 gr., as given on 7th and 8th June. Blood film examined for malaria on 6th June, and blood culture for enteric group on 12th June; both gave negative results.

A sympathetic pleural effusion is occasionally of sufficient size to allow of clinical recognition, or in some cases evidence of pleural irritation suggests some subphrenic inflammation.

Blood examination often supplies valuable information, and a relative increase in the percentage of polymorphonuclear cells is of assistance in distinguishing between simple and suppurative hepatitis. An illustration of the value of a differential cytological examination concerns a patient who was admitted to hospital with an enlarged and tender liver, slight fever and diarrhœa. The total white cell count was 18,500 per c.c., but only 60 per cent. were polymorphonuclear. A diagnosis of dysenteric hepatitis was made, and the condition subsided under a suitable diet and emetine injections.

Radiographic examination is a valuable aid to diagnosis in doubtful cases (Fig. 827). Three points are of assistance in confirming the presence of a liver abscess:—

1. Increase in the size of the liver in an upward direction.
2. Limitation of movement of the diaphragm the normal $1\frac{1}{2}$ in. excursion is reduced to $\frac{1}{2}$ in. or less.
3. The normal dome-shaped convexity is sometimes distorted by a bulge which represents a pointing abscess.

Treatment—Amœbic hepatitis is the precursor of a liver abscess and suppuration is doubtless prevented in many instances by the exhibition of emetine or E.B.I. together with confinement to bed and suitable diet.

Suppuration is to be suspected if the temperature continues to oscillate

ruptures any intrahepatic septa that might interfere with drainage A rubber drainage tube is inserted and meticulous care is observed during subsequent dressings so as to avoid the advent of superadded infection

Lateral route—Preliminary aspiration is advisable so that the exact site of the abscess can be discovered When pus is withdrawn the needle is allowed to remain *in situ* as it forms a valuable guide to the abscess About 2 in of the rib below the needle is excised and in practically all cases the parietal pleura is adherent to the pleura which covers the diaphragm so that suture of the two layers of pleura is unnecessary The diaphragm is incised across the muscular fibres so that retraction occurs and drainage is therefore unhampered Either sinus forceps or a finger is passed along the needle into the abscess and gentle digital exploration investigates for the possibility of any loculi A drainage tube is then inserted and stitched to the skin and if considered advisable the tube is connected to a suction apparatus

Posterior route—If clinical and radiological evidence suggest that the abscess is in the lower and posterior part of the right lobe posterior drainage should be attempted The incision is made over the area of maximum swelling or œdema which is usually immediately below the twelfth rib It is often an advantage to excise the rib subperiosteally especially if the rib reaches farther forwards than the posterior axillary line If the abscess does not present itself aspiration of the liver is necessary and when pus is located drainage i obtained by the most dependent route

Rupture of an abscess is the most likely termination in cases which are undiagnosed or untreated The more common situations in which an abscess ruptures are depicted in Fig 828 In addition the inferior vena cava and portal veins have been eroded with fatal results and pus has also been discharged into the biliary passages and pelvis of the right kidney

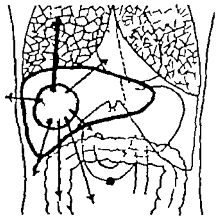

FIG 828

Directions in which a tropical liver abscess may burst. (*After Cope*)

Rupture of an abscess occurs most commonly into the lung or more correctly into a branch of the right bronchus The sequence of symptoms is as follows pain in the shoulder owing to irritation of the diaphragm a dry persistent cough following involvement of the pleura and finally the expectoration of pus Sudden rupture of a large abscess may even produce suffocation In suspected cases a radiograph occasionally reveals an abscess which distorts the dome of the diaphragm The expectoration of pus renders the diagnosis obvious and most cases subside in a satisfactory manner under suitable treatment Rupture into a hollow viscus results in the pus being either vomited or passed per rectum in either case spontaneous cure is likely Occasionally an abscess bursts into the peritoneal cavity with all the features of a sudden abdominal catastrophe As soon as the condition of the patient permits the abdomen is opened pus mopped out and drainage instituted but the prognosis is serious

and presumably too thick to flow, for it is improbable that with so many abscesses present one or more were not tapped

The needle, which is graduated at intervals of half an inch, should not be introduced to a greater depth than 4 in (or 3½ in in a thin patient), otherwise the inferior vena cava or the portal vein may be reached The needle is connected with a Potain's aspirator or a Record syringe, and is first introduced in the ninth right intercostal space in the anterior axillary line The needle is directed backwards and slightly upwards, so that it passes towards the dome of the right lobe Suction is applied at intervals, and in the absence of pus a drop or two of blood is usually obtained If the needle appears to be blocked, a stilette is passed along it so as to clear it of liver débris If pus is not discovered, the needle is withdrawn and reinserted through the space above, *i e*, the eighth intercostal space If the result is negative, aspiration is performed through the ninth and eighth spaces in the mid-axillary line and finally through the spaces in the posterior axillary line, bearing in mind that the more posteriorally the needle is inserted the shorter is the distance to the large veins Lateral movements of the needle during aspiration are to be deprecated, as trauma to the liver is thereby encouraged, and, should an intrahepatic vein be impaled on the point of the needle, damage to the vein wall, and consequent extravasation of blood, are liable to occur

When pus is discovered aspiration is proceeded with until the cavity is emptied A useful manœuvre is to inject an occasional syringeful of quinine bihydrochloride solution (a drachm to a pint), which not only helps to liquefy the pus, but which is also a powerful amœbicide Aspiration should be conducted in a leisurely manner, so that the walls of the cavity are encouraged to collapse gradually, and in order to enable displaced viscera to regain slowly their more normal situations Moreover, sudden decompression of an abscess encourages capillary oozing from the wall of the cavity Typical pus is classically described as resembling anchovy sauce, but obvious modifications, both as regards colour and consistency, are common A second, or even more aspirations are sometimes required, and the pus obtained should be examined by a bacteriologist in order that superadded infection can be recognized Amœbæ are more likely to be found in pus which is obtained towards the end of the aspiration Pus from the centre of the abscess is commonly sterile, but as the abscess collapses amœbæ seem to be squeezed out of the wall, and are usually to be found in the last ounce or so of pus

Open operation and drainage is required if mixed infection occurs, or if the abscess is in relation to the anterior abdominal wall Also it is occasionally necessary to explore the liver when a suspected abscess is not discovered by needling and aspiration Exploration of the liver is conducted by the anterior, lateral or posterior routes

Anterior route—The abscess is usually visible or palpable beneath the anterior abdominal parietes, which probably form part of the wall of the abscess An incision is made over the most prominent part of the swelling, and the fibres of the rectus muscle are split Displacement of the muscle interferes with drainage The abscess is opened and adhesions to surrounding organs are respected The cavity is explored with a cautious finger which

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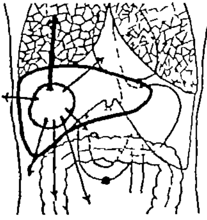

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factors As already mentioned small abscesses probably absorb under the influence of emetine or possibly without it

Under modern treatment a single abscess in the absence of secondary infection and within reach of aspiration carries little risk provided that the general condition of the patient is satisfactory

ABSCESSES IN OTHER SITUATIONS—The liver is a very efficient filter and it is unusual for amœbæ to enter the systemic circulation When such an event does occur it is possible for amœbic abscesses to develop in various parts of the body but for some reason the brain and epididymis are particularly susceptible

BACILLARY DYSENTERY

Bacillary dysentery is a widespread disease It is common in tropical countries, it frequently occurs in subtropical districts and occasionally causes epidemics in temperate zones. The two bacilli mainly responsible for the disease were discovered respectively by Shiga in 1897 and Flexner in 1900. Sonne's bacillus is a less pathogenic member of the same group and causes epidemics of mild dysentery in temperate climates. The laboratory distinctions between these various bacilli are beyond the scope of this chapter Shiga's bacillus is responsible for the most severe clinical manifestations of bacillary dysentery but mixed infections commonly occur

Bacillary dysentery mainly affects the large bowel from the sigmoid colon to the anal canal In its most acute form the course of the disease resembles that of cholera Acute toxæmia with incessant passage of watery or blood-stained stools terminates fatally after an illness of only two or three days duration More commonly the disease is partially controlled but it relapses on the slightest or even no apparent provocation The diagnosis of bacillary dysentery can usually be confirmed in the laboratory but in chronic cases sigmoidoscopic examination is valuable Small ridges of granulation tissue with local patches of hyperæmia are very suggestive

Medical treatment comprises confinement to bed saline aperients sedative mixtures containing belladonna and opium to relieve tenesmus a suitable diet composed mainly of easily digestible protein and anti-dysenteric serum which is only efficacious in the acute stages of the disease Major A C King F R C S is of the opinion that chloretone in doses of 5 gr repeated as necessary acts as a specific in relieving the acute discomfort associated with tenesmus In severe cases serum (40 c c or more) diluted with saline is injected intravenously otherwise the intramuscular route is employed The least uncomfortable site for an intramuscular injection of small or moderate bulk is into the vastus externus muscle which locality is unaffected by respiratory movements or by movements of the upper limb (restriction of which is so irksome to a bedridden patient) and the site of the injection is free from pressure Colonic lavage is valuable in many cases saline (1 in 40) eusol (half strength) and silver nitrate (1 in 150) are commonly used

Surgical treatment should be undertaken when it is apparent that the patient is unlikely to respond to medical measures The objects of surgical treatment are to permit of more efficient lavage and to provide rest for the inflamed gut Three surgical measures are available—appendicostomy cæcostomy and ileostomy

APPENDICOSTOMY is the simplest method provided that the appendix is adequate in length and not fibrosed The organ is exposed through a gridiron incision and the cæcum is sutured to the parietes so that the distal part of the appendix projects through the wound The vessels in

External rupture is preceded by a local swelling over which the parietes eventually become tender and œdematous Finally, fluctuation is apparent, and rupture is then not far distant In the early stages treatment by aspiration is the method of choice, but when the parietes form part of the abscess wall incision and drainage is necessary The commonest situation for an abscess to present itself is under the right costal margin, and the condition may be indistinguishable from an empyema of the gall-bladder

Prognosis—The following factors must be taken into consideration when reviewing the prognosis of a liver abscess

Acuteness of the attack—Hepatic infection which occurs concurrently with or soon after an attack of amœbic dysentery is more virulent, and more liable to result in multiple abscesses, than infection which is delayed or which is associated with chronic dysentery Hepatic suppuration occasionally develops within a very short time of infection In a case under the writer's care a man of twenty-three arrived in the tropics from England, and there was no occasion to suspect any dysenteric infection while on the voyage He developed amœbic dysentery within a few days of his arrival, and in less than four weeks a pint of pus, from which amœbæ were recovered, was evacuated from his liver Fortunately only one abscess was present (unless smaller ones absorbed), and he recovered with the assistance of emetine

Resistance of the patient—Alcoholic patients appear to be more prone to abscess of the liver than more temperate people While a reasonable amount of alcohol after sundown is beneficial to most tropical dwellers, an excess is liable to lower the resistance of the patient in general, and that of his liver in particular

In addition to resistance of the individual, the circumstances under which a community lives must be taken into consideration For example, during the campaign in Mesopotamia heat and privation caused grave disability among British soldiers, and in thirty consecutive cases under the writer's care the immediate mortality was 63 3 per cent Also, although the survivors were evacuated, there was no guarantee that a recurrence could be excluded

Site of infection—The most suitable place for an abscess to form is the centre of the right lobe of the liver Here it can be located readily with a needle and aspirated with safety Moreover, it is surrounded by a safety margin of liver tissue In proportion to the size of the two lobes of the liver, abscesses occur at least as frequently in the left lobe as in the right An abscess in the left lobe is more difficult to diagnose than one on the right side, and needling is a precarious undertaking with the pericardium above, the spleen to the left and the stomach below ! Procrastination in treatment is therefore often understandable, and relief is obtained if the abscess ruptures into the stomach or colon, or presents itself beneath the abdominal wall—a welcome offering for the surgeon's scalpel

An abscess of the Spigelian lobe, unless it extends in a more favourable direction, is beyond the reach of an aspirating needle, and is likely to be fatal unless it ruptures into a suitable organ or responds to treatment The only case seen by the writer caused sudden death by erosion of the inferior vena cava

Early diagnosis and suitable treatment are naturally important

epidemics It is especially liable to follow infection by the Shiga bacillus The comparatively late onset of the arthritis distinguishes it from serum reactions Moreover fluid aspirated from a distended joint will agglutinate the dysentery bacillus The majority of cases resolve but in the worst instances some degree of fibrous ankylosis may result

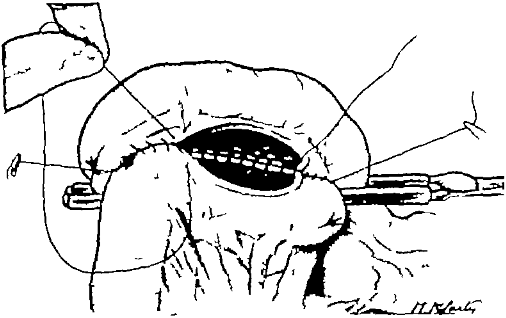

FIG 820
Ileo-colostomy by side-to-side anastomosis. (*Royal Northern Operative Surgery*)

Conjunctivitis frequently occurs in association with arthritis and in some cases the deeper structures of the eye are affected *e.g* iritis or irido cyclitis Peripheral neuritis is an occasional manifestation of toxic absorption Stenosis of the colon due to fibrosis is apt to affect patients who are fortunate enough to survive extensive ulceration

FILARIASIS

This disease common in tropical and subtropical countries is transmitted by the females of certain types of mosquitoes The adult or parent parasite commonly known as filaria sanguinis hominis is found in the lymphatics of man These nematodes are long and thin and measure two or three inches in length The female gives birth to countless microfilariæ about a quarter of a centimetre long which are found in the blood especially at night Serological and intradermal tests confirm the diagnosis in doubtful cases

The surgical importance of filariasis lies in its pathological effect on the lymphatic system Two main varieties of disease result *lymphatic varix* and elephantiasis

Lymphatic varix is due to obstruction of the larger lymphatic vessels, so that collateral lymphatics undergo a compensatory dilatation The degree of dilatation may be enormous and rupture is prone to occur Thus chylous ascites results when a distended lymphatic ruptures into the

the mesentery are carefully preserved In cases which are not urgent the appendix is cut across three days later, and a catheter is passed into the cæcum so that fluid can be introduced for the purpose of irrigation Direct lavage of the large bowel can thus be obtained, but as the cæcum can be reached by injections per rectum little is gained by this procedure, except a more comfortable method of lavage

CÆCOSTOMY is performed by the "ink-bottle" method of Kader-Senn A pouch of cæcum is withdrawn through a gridiron exposure, and a Paul's tube is introduced between two purse-string sutures The cæcum is sutured to the parietal peritoneum, and the Paul's tube becomes loose and is removed about six days later Free lavage is easily procured through the cæcostomy opening, but the amount of fæcal drainage, and consequent mechanical rest to the colon, is variable Possibly this depends on the variability of anti-peristaltic movements in the ascending colon of individual patients

ILEOSTOMY is the only operation which provides the maximum degree of rest to the inflamed colon By this means intestinal contents are completely diverted, so the colonic mucosa is not mechanically irritated by food, nor is the muscle stimulated by residue in the lumen In the writer's experience ileostomy is the method of choice when surgical interference is deemed to be necessary It appears that the essential need of the dysenteric colon is rest, and the following case furnishes an example of this principle

A male, aged thirty six, was admitted on 20th July as dysentery The attack began one month before admission, and on admission he was passing seven to ten stools a day, containing blood and mucus, and large numbers of entamœbæ histolyticæ were present In spite of medical treatment, his condition gradually deteriorated, and his weight slowly but regularly fell Towards the end of September his pulse began to increase (110 to 120) and to become irregular, and it became obvious that medical treatment held out little chance of success On 7th October cæcostomy was performed, and a Paul's tube tied in, which sloughed off in five days Free drainage was obtained, very little fæcal matter being passed per rectum The large intestine was flushed through twice a day with weak quinine and eusol alternately, and the patient very soon began to improve His bowel condition was satisfactory up to the end of the third week after the operation, and he was already looking and feeling better Unfortunately, at this time, drainage from the cæcostomy diminished, although efforts were made to keep the aperture patent by dilatation, but drainage remained inadequate, there being less and less discharge from the fistula The patient's condition began to deteriorate rapidly, diarrhœa with blood and mucus returning and the pulse increasing in rate Ileostomy was performed five weeks after the operation for cæcostomy An incision was made 1 in above and to the inner side of the cæcostomy wound, the ileum divided close to the cæcum, the lower end closed and the upper end brought out through the incision and a Paul's tube tied in The cæcostomy wound was allowed to close completely, being utilized for lavage as long as possible After a few days the Paul's tube sloughed from the ileostomy, and the patient's condition rapidly improved, appetite and ability to take food increased, he put on weight, and a month after the second operation he sat out of bed, the first time for six months Six weeks after the operation rectal wash outs with saline were returned without any trace of blood or mucus, and no amœbæ could be found Six weeks later it was deemed that the time was ripe for the closure of the ileostomy An incision was made which encircled the ileostomy, and the bowel was dissected from the abdominal wall The ragged portion of gut close to the opening was excised and closed The ileum was then united to the transverse colon by means of a side-to side anastomosis (Fig 829) The patient made an uneventful recovery

Terminal ileostomy [1] is sometimes indicated in cases of ulcerative colitis, when other means fail Many gratifying results have been published, a typical one being that reported by Rupert Corbett to the Royal Society of Medicine (see reference)

Complications—Arthritis, especially affecting larger joints, such as the ankle or knee, is a common complication during convalescence in some

[1] In cases of ileostomy, ferri redactum, 5 gr, t d s, has a beneficial influence in preventing excoriation of the skin

gubernacular fibres are divided and the spermatic cords isolated as far as the external abdominal rings so as to permit the testicles to be placed in safety on the abdominal wall The scrotum is then excised and hæmostasis is secured Flaps of the scrotal margin and skin of the thigh are then dissected up on either side so as to form a pocket for each testicle and the scrotal wound is closed with dependent drainage Thiersch skin grafts are then applied to the penis which is covered with tulle gras and dressed with 1 per cent aqueous picric acid solution It is a wise precaution to tie in a catheter for a few days in order to forestall retention of urine and also to prevent soiling of the dressing The operation is rendered more formidable if the scrotal neck is wide rather than narrow and the greater the amount of skin which can be removed the less likelihood is there of recurrence Any suspicion of post-operative infection is an immediate indication for sulphonamide therapy

Elephantiasis of other regions of the body such as that of the arms vulva or breasts is treated by rest elevation pressure or excision according to the part affected.

SCHISTOSOMIASIS (SYN BILHARZIOSIS)

The parasite responsible for genito urinary schistosomiasis was discovered by Bilharz in Cairo ninety years ago The disease is an ancient one as ova have been recovered from Egyptian mummies The three most important varieties of parasites are S mansoni which mainly affects the lower portion of the bowel S hæmatobium which attacks the genito urinary tract and S japonicum which is prevalent in China and Japan and not only affects the lower intestinal tract but also causes enlargement of the spleen and liver which is eventually followed by cirrhosis and ascites

The structure and life history (Fig 832) of these parasites varies only in detail. Briefly the history of S mansoni is as follows the adult parasites are found in the veins of the portal system. The male which is about half an inch in length is capable of partially enveloping the female by infolding the lateral expansions of its body so as to form a gynæcophoric canal The female is rather larger than the male so that when in the male s embrace the anterior and posterior ends of the female protrude from the gynæcophoric canal (Fig 832) The paired worms travel against the blood stream and two ventral suckers which are situated at the anterior end of each worm enable them to adhere at intervals to the wall of the vein along which they travel in their journey towards the venous radicles in the bowel. The female then leaves the male and deposits the ova in the smallest venules The passive egg is actively squeezed into the lumen of the gut by contraction of the muscle in the bowel wall, and its passage is facilitated by the lateral spine with which it is provided (Fig 833) and which is of material assistance as it is forced through the layers of the gut The egg is passed in the fæces and when diluted with water reduced osmotic pressure causes rupture of the shell. The embryo or miracidium thus escapes This is a ciliated organism which seeks a fresh water snail which is the intermediary host The miracidium gains entrance to the snail through the antennæ and forms spirocysts from which bifid tailed cercariæ emerge about six weeks after

peritoneal cavity, or chyluria follows the discharge of lymph into the bladder or a kidney

Elephantiasis is a more important condition from the surgical aspect, and operative treatment can ameliorate or even cure the disease in some parts of the body The characteristic œdema is possibly due to toxic irritation in addition to that caused by lymphatic obstruction Recurrent attacks of inflammation, due to superadded streptococcal infection, are of common occurrence Suppuration and abscess formation may result

Elephantiasis of the legs usually ends abruptly at the level of the knee Enormous dimensions are sometimes attained and papillomatous outgrowths frequently occur on the feet Treatment consists in the early cases of elevation and pressure by elastic or other bandages, but relapse is to be expected if the patient resumes walking Lymphangioplasty is disappointing, and usually infection of the material used in the operation renders subsequent removal necessary

Fig 830
An early case of elephantiasis of the scrotum

Kondoléon's operation consists in excision of long strips of deep fascia, the object being to remove the fascial barrier between the superficial and deep lymphatics so that lymph can return by the latter channel Excision of strips of skin and subcutaneous tissue, including any fistulæ which are the legacy of previous abscesses, assist in reducing the weight of the leg and so rendering walking less difficult

Elephantiasis of the scrotum causes obvious disabilities, which are commonly aggravated by recurrent attacks of inflammation Twenty pounds or more is a common weight for an elephantoid scrotum (Fig 830) When physical discomfort and mental distress warrant it, surgical removal is the only treatment of avail The patient should be in bed for a week before the operation so that rest and elevation can assist in reducing the size and vascularity of the swelling Careful preparation of the skin is important, as post-operative infection is prone to occur and accounts for the majority of fatalities Spinal anæsthesia is desirable The position of the patient is indicated in the accompanying figure (Fig 831), wide abduction of the legs allows the scrotal mass to be rolled from side to side as circumstances require A vertical incision is made from the symphysis to the aperture leading to the penis, and the latter organ is freed from surrounding tissue A sound is then introduced so that the urethra can be identified during subsequent dissection The vertical incision is then carried around the scrotum, and is deepened so as to expose the testicles. The

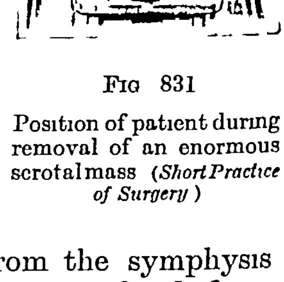

Fig 831
Position of patient during removal of an enormous scrotal mass (*Short Practice of Surgery*)

gubernacular fibres are divided and the spermatic cords isolated as far as the external abdominal rings so as to permit the testicles to be placed in safety on the abdominal wall The scrotum is then excised and hæmostasis is secured. Flaps of the scrotal margin and skin of the thigh are then dissected up on either side so as to form a pocket for each testicle and the scrotal wound is closed with dependent drainage Thiersch skin grafts are then applied to the penis which is covered with tulle gras and dressed with 1 per cent aqueous picric acid solution It is a wise precaution to tie in a catheter for a few days in order to forestall retention of urine and also to prevent soiling of the dressing The operation is rendered more formidable if the scrotal neck is wide rather than narrow and the greater the amount of skin which can be removed the less likelihood is there of recurrence Any suspicion of post-operative infection is an immediate indication for sulphonamide therapy

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SCHISTOSOMIASIS (SYN BILHARZIOSIS)

The parasite responsible for genito-urinary schistosomiasis was discovered by Bilharz in Cairo ninety years ago The disease is an ancient one as ova have been recovered from Egyptian mummies The three most important varieties of parasites are S mansoni which mainly affects the lower portion of the bowel S hæmatobium which attacks the genito urinary tract and S japonicum which is prevalent in China and Japan and not only affects the lower intestinal tract but also causes enlargement of the spleen and liver which is eventually followed by cirrhosis and ascites

The structure and life history (Fig 832) of these parasites varies only in detail Briefly the history of S mansoni is as follows the adult parasites are found in the veins of the portal system The male which is about half an inch in length is capable of partially enveloping the female by infolding the lateral expansions of its body so as to form a gynæcophoric canal. The female is rather larger than the male so that when in the male s embrace the anterior and posterior ends of the female protrude from the gynæcophoric canal (Fig 832) The paired worms travel against the blood stream and two ventral suckers, which are situated at the anterior end of each worm, enable them to adhere at intervals to the wall of the vein along which they travel in their journey towards the venous radicles in the bowel. The female then leaves the male and deposits the ova in the smallest venules The passive egg is actively squeezed into the lumen of the gut by contraction of the muscle in the bowel wall and its passage is facilitated by the lateral spine with which it is provided (Fig 833) and which is of material assistance as it is forced through the layers of the gut The egg is passed in the fæces and when diluted with water reduced osmotic pressure causes rupture of the shell The embryo or miracidium thus escapes This is a ciliated organism which seeks a fresh water snail which is the intermediary host The miracidium gains entrance to the snail through the antennæ and forms sporocysts from which bifid tailed cercariæ emerge about six weeks after

the snail has been invaded The cercariæ are visible to the naked eye as they swim in water They perish within two days unless they are fortunate enough to find and penetrate the skin of a suitable mammal, such as man They then make their way by blood vessels or lymphatics to the liver of their definitive host, where, after an interval of about six weeks, they reach maturity

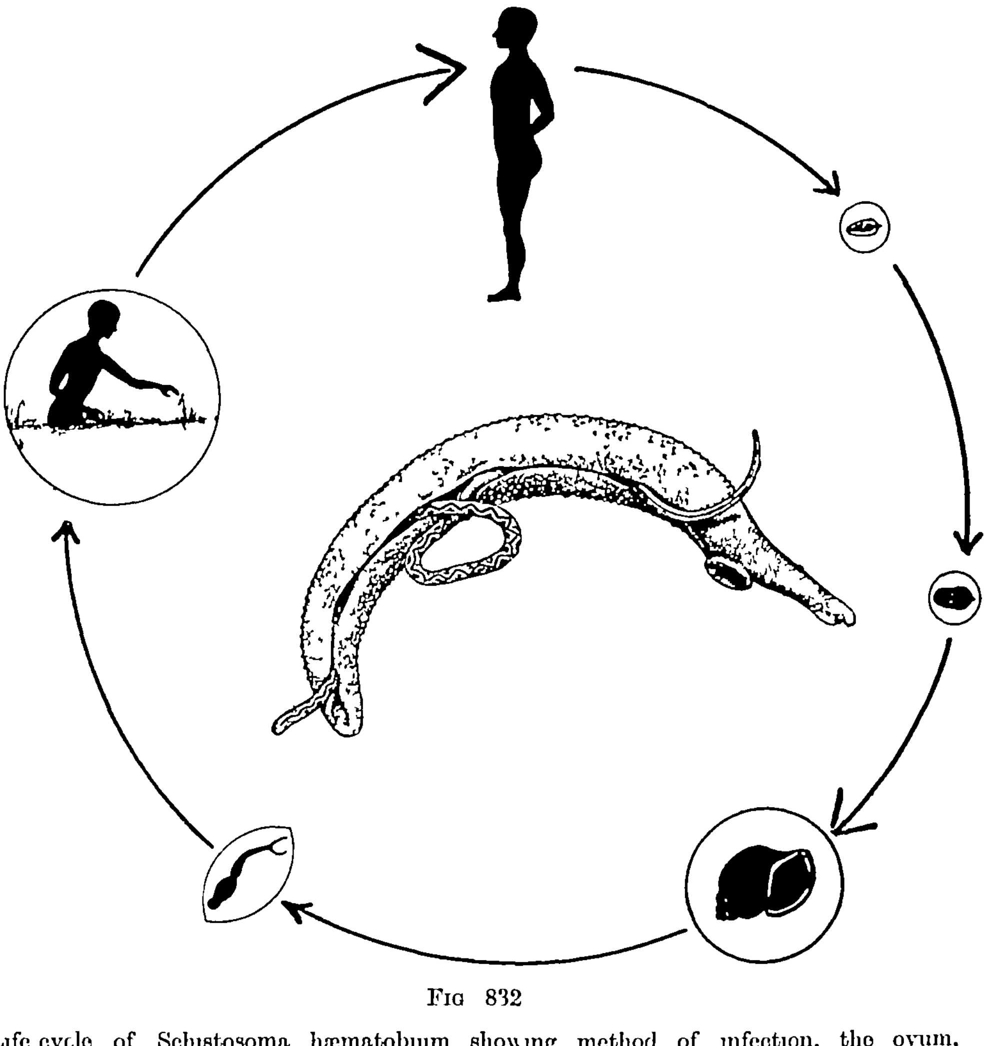

FIG 832

Life cycle of Schistosoma hæmatobium showing method of infection, the ovum, miracidium, the intermediate host (snail), and the cercaria Inset is a male worm which has enveloped a female in the gynæcophoric pore (*Wellcome Museum*)

The life-history of S hæmatobium is similar, but the parasites are somewhat larger than those of the S mansoni, and the ova possess terminal spikes instead of lateral ones (Fig 834) The S japonicum is the smallest of the members of this group, and the ova are spineless Its main ravages are confined to the rectum

The surgical manifestations of schistosomiasis depend upon the type of parasite S hæmatobium mainly affects the genito-urinary system and causes frequency and dysuria, which is followed by cystitis and hæmaturia, so that the condition justifies the Egyptian name of endemic hæmaturia Cystoscopy

reveals polypoid excrescences of granulation tissue in the bladder (Fig 835) The rectum and anal canal are sometimes involved The patient eventually becomes worn out with cystitis peri vesical abscesses pyelitis and loss of

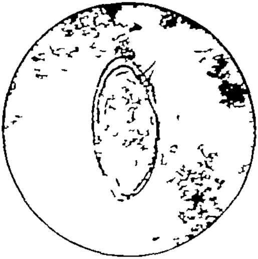

FIG 833

S. mansoni

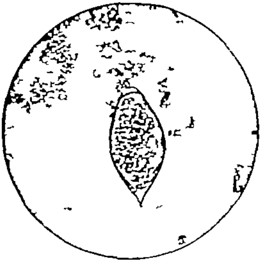

FIG 834

S hæmatobium. (Wellcome M seum.)

blood The characteristic ova are found in the urine especially if the last few drachms are collected separately and examined Ova which fail to escape from the prostate eventually become calcified a condition sometimes referred to as a sandy prostate

FIG 835

Cystoscopic appearance in bilharzia disease of the bladder

(Christopherson and Ward "British Journal of Surgery")

S mansoni infection results in symptoms which somewhat resemble dysentery in that diarrhœa tenesmus and the passage of blood-stained fæces and mucus are prominent features Eventually polypoid masses form in the mucosa of the lower bowel and sinuses and fistulæ appear in the anal region The liver is sometimes cirrhotic

S japonicum resembles S mansoni in its clinical manifestations, but splenomegaly and hepatic involvement are more prominent features

The incubation period of schistosomiasis varies from three months to two years, so symptoms may present themselves long after a patient has left an infected area

In the majority of cases the diagnosis is clinched by the discovery of the characteristic ovum, but if any doubt exists, or in early cases before the passage of ova, a complement deviation or intradermal test are valuable accessory aids to diagnosis

Treatment—Intravenous injection of sodium-antimony tartrate (tartar emetic) popularized by Christopherson, has revolutionized the treatment of schistosomiasis The preliminary dose is ½ gr of tartar emetic in 10 c c of distilled water The dose is increased by ½ gr and given alternate days up to 2½ gr for each injection, and treatment ceases when 30 gr have been administered

Patients with a low limit of tolerance to antimony develop an intractable cough, which acts as a warning The dose should then be reduced, otherwise vomiting and cardiac depression will result In most cases, towards the end of a course of treatment, it is wise for the patient to lie down for a few moments after the injection The injection is best given between meals, as an empty stomach discourages vomiting In sensitive patients a moderate dose of omnopon (¼ to ⅓ gr), given half an hour before the injection, modifies the toxic manifestations

Fouadin is a proprietary preparation of antimony (Bayer), which can be given intramuscularly This simplifies treatment, especially in children or in patients with small veins, and the length of treatment is shorter than in the case of intravenous tartar emetic Emetine, administered either intramuscularly or orally, gives results nearly as dramatic as those obtained from antimony, but it is much more expensive

Fig 836

Case of cutaneous Leishmaniasis of lupoid type affecting upper lip The white area is covered by dry epithelial scales Cured by a few intravenous injections of 1 per cent tartar emetic Patient contracted the disease in Persia
(*British Journal of Surgery*)

Operative treatment of schistosomiasis is conducted on general principles Thus cystostomy or removal of vesical calculi may be required for S hæmatobium infections In the case of S mansoni, perineal fistulæ or abscesses are opened, or in severe cases a colostomy is required as a precursor to medical treatment Splenectomy has been largely superseded by efficient antimony therapy

LEISHMANIASIS

Three important tropical diseases comprise the main members of this group They are the oriental sore, which is a cutaneous infection (Fig 836), kala-azar or visceral leishmaniasis, and espundia, in which the nasal

and buccal mucous membranes are affected

The parasite of leishmaniasis known as the Leishman Donovan body is an ovoid organism varying between 2μ and 4μ in diameter (Fig 837) When stained by Leishman's method the appearance is characteristic The chromatin masses one much larger than the other are easily recognized enclosed in a cytoplasm which is bluish in colour The parasites inhabit endothelial cells and they are sometimes found in white corpuscles There is increasing evidence to indicate that the dog is the main reservoir of this disease and stray dogs should be destroyed The organism is carried from dog to dog and from dog to man by the Phlebotomus perniciosus

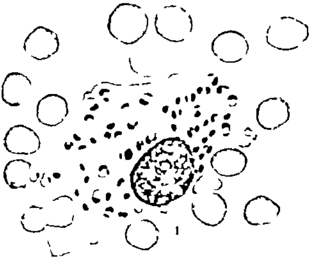

Fig 837

Leishman Donovan bodies in kala-azar (*Manson's Tropical Diseases.*)

ORIENTAL SORE

This cutaneous infection is also referred to as Delhi or Baghdad boil In the latter district it is uncommon to meet a local inhabitant who is not disfigured with one or more scars In the Tigris valley the disease becomes epidemic during the early autumn As sand flies are most rampant during the height of the hot season this suggests that the average incubation time is two or three months

Fig 838

Dermal leishmaniasis. The patient was an Egyptian girl, aged eleven years. (*D H K Griffin*)

The lesion begins as an itching papule which gradually breaks down to form a shallow ulcer (Fig 838) This ulcer slowly extends and the discharge not infrequently dries on the surface so as to form a crust After an average lapse of six to twelve months the ulcer begins to heal gradually and ugly or contracted scars are

Fig 839

Multiple Baghdad boils on the leg of a Mesopotamian Arab girl.

liable to result Multiple ulcers are not uncommon especially in the extremities (Fig 839)

Diagnosis is confirmed by identification of the Leishman-Donovan body in serum obtained from the ulcer Early recognition and treatment is desirable so as to prevent extension of the ulcer and limit subsequent disfigurement

General treatment consists essentially in intravenous administration of antimony tartrate A 2 per cent solution is commonly used, and a total of 15 gr is usually adequate , other derivatives of antimony may be preferred (see p 882)

Local treatment, in its simplest form, consists in cleaning the scabs and crusts from the sore with antiseptic compresses and applying one of the numerous preparations which seem to give good, but variable, results The following preparation is strongly recommended by Manson-Bahr —

℞ Cignolin		gr iv
Ichthyol		gr viii
Ol Cadini		♏xl
Benzoli rect	ad	℥i

Cignolin is a refined product of chrysophanic acid The preparation is painted on the sore daily for a period of two to four weeks Many proprietary preparations are obtainable, but the very largeness of their numbers indicates that no specific remedy is available

Surgical treatment—Excision of a sore is an excellent method of treatment, provided its size and site lend themselves to this procedure Excision is followed by primary or secondary suture Scraping an ulcer frequently stimulates healing, and skin grafts can be applied subsequently in selected cases Carbon dioxide snow is efficacious in the treatment of ulcers of limited size and, if facilities exist, ionization or X-ray therapy give good results

Fig 840 Egyptian splenomegaly (*H E R Stiven*)

KALA-AZAR (SYN TROPICAL SPLENOMEGALY)

This disease is characterized by bouts of irregular fever, associated with wasting, and progressive enlargement of the spleen, and usually the liver In spite of fever and abdominal enlargement the patient is often surprisingly well and active In the later stages emaciation and anæmia are severe, and hæmorrhages are apt to occur, such as epistaxis or purpura Œdema of the legs and ascites supervene, and the patient gradually assumes a peculiar greyish colour, from which the name of the disease (kala-azar, or "the black disease") is derived

The condition must be distinguished from other forms of splenomegaly, notably splenic anæmia and Egyptian splenomegaly (Bilharzia mansoni) (Fig 840) Cytological examination of the blood reveals a leucopænia, and in severe cases agranulocytosis develops The diagnosis is clinched by finding Leishman-Donovan bodies in splenic pulp or bone marrow, either of which are obtainable by puncture Splenic puncture is performed under local anæsthesia, and abdominal movements are restricted by means of a binder

A clean dry hypodermic needle is used and the patient instructed to hold his breath when the puncture is made A little splenic pulp is withdrawn into the needle and expelled on to a slide and stained by Leishman s method Preliminary administration of calcium is said to diminish the risk of hæmorrhage Sternal puncture is considered by some authorities to be preferable to puncture of the spleen in that there is no risk of hæmorrhage and the marrow is more likely to contain parasites Under local anæsthesia a stout needle with a stylet is introduced through the skin at the level of the angle of Louis and pushed obliquely into the manubrium a boring movement assists its passage through the compact layer of bone When this is pierced a syringe is attached to the needle and aspiration performed A simple method of diagnosis suggested by Kirk is aspiration of enlarged lymphatic glands with a hypodermic needle The aspirated fluid contains parasites which can easily be stained and recognized This method of diagnosis is similar to that used for the B pestis

Various chemical reactions of the blood serum from kala azar patients have been described but they are not sufficiently reliable for positive diagnosis in all cases

The treatment of kala azar consists in an appropriate course of antimony therapy which is a specific in this disease In the absence of associated infection such as dysentery malaria or tuberculosis recovery can be expected in all but very advanced cases

ESPUNDIA (SYN LEISHMANIASIS AMERICANA)

This manifestation of leishmaniasis is prevalent in South America The disease mainly affects the nasal and buccal cavities which eventually become extensively ulcerated The Leishman Donovan bodies are present in scrapings from the ulcers or found by biopsy The condition responds to a course of antimony therapy combined with local treatment directed towards keeping the ulcerated surfaces as clean as possible

ENDEMIC FUNICULITIS

Swelling and tenderness of the spermatic cord not uncommonly occurs in subtropical climates and is occasionally seen in temperate zones According to Castellani it is due to thrombo-phlebitis of the pampiniform plexus which is sometimes complicated by streptococcal infection The cord becomes enlarged rubbery in consistency and painful

Treatment is symptomatic and sulphonamide therapy is worthy of trial

YAWS (SYN FRAMBŒSIA)

Space forbids more than a brief reference to this infection which is particularly rife in Africa and southern India The specific organism is the Spirochæta pertenuis which is morphologically serologically and culturally indistinguishable from the Spirochæta pallida The clinical ravages caused by the two organisms are distinctive but both are equally susceptible to

the same therapeutic measures, with the exception that the oral administration of mercury is useless as a remedy for yaws

Yaws is a non-venereal disease which is extremely contagious, and children are commonly infected (Fig 841), either by direct contact or by an intermediary fly which infects a pre-existing sore or wound The disease is not congenital, and, as would be expected, it is particularly rife among those who waive personal cleanliness and elementary sanitary precautions

The incubation period varies between two and four weeks, and is accompanied with a slight elevation of temperature, malaise and vague pains As in the case of syphilis, the progress of the disease can be divided into the primary, secondary and tertiary stages

Primary stage—The site of inoculation may be on any part of the body, particularly below the knee, or, in the case of nursing mothers, on the breast A papule appears which exudes a serous discharge This dries to form a scab, which, when removed, exposes a granulating, indolent ulcer Regional lymphatic glands are enlarged and firm The primary stage lasts for a period of two or three months, and may subside before the secondary stage appears

FIG 841

Primary yaws on the lips of an Australian aboriginal child (*Dr H Basedow, by the courtesy of Sir P Manson-Bahr*)

Secondary stage—Multiple eruptions appear, associated with itching and constitutional disturbances The itching distinguishes the condition from the secondary manifestation of syphilis Desquamation of the skin is a common feature, and, if localized, appears as white patches, which are very characteristic if seen against a background of dark skin The Wasserman reaction is now positive

Tertiary stage—Lesions now occur which resemble those of tertiary syphilis, except that the viscera and the cardio-vascular system are seldom affected Cutaneous nodules appear, which soften to form indolent ulcers Periostitis is common, and a characteristic manifestation afflicts the nasal processes of the superior maxillæ, resulting in enormous enlargement (goundou) Periarticular nodules and synovitis are of common occurrence

Treatment—Arsenical preparations exercise the same dramatic effect on the ravages of yaws as they do in the case of syphilis Treatment on a mass scale is, however, prohibitive, on account of the cost Fortunately, bismuth salts exercise almost as potent a therapeutic effect as those of arsenic, at a small portion of the cost Combined treatment, *i e*, alternating weekly doses of intravenous neosalvarsan and intramuscular bismuth, yields excellent results

CHOLERA

Cholera is an acute specific infection due to the comma bacillus The organisms can only be distinguished from non pathogenic vibrios by agglutination tests Prophylactic inoculation confers immunity for a period of about six months

The surgical importance of cholera lies in the necessity for replenishing loss of fluid and salts from the circulation In addition during the stage of evacuation dangerous acidosis is liable to occur which may engender suppression of urine and fatal uræmia The oral administration of alkali is useless so intravenous administration is essential The preparation recommended by Rogers and Megaw is a solution containing 90 gr of sodium chloride and 160 gr of sodium bicarbonate to a pint of water In order to avoid decomposition of the sodium bicarbonate by boiling it is sterilized in packets of 160 gr and added to the hypertonic sodium chloride solution immediately before injection One pint of this alkaline solution is followed by 3 pints of hypertonic saline solution (120 gr to 1 pint to which may be added 4 gr of calcium chloride which is said to stimulate the cardiac musculature) In collapsed patients an incision is frequently necessary in order to gain entrance to a vein, and the fluid is administered by the drip method

Permanganate of potash destroys the toxins in the alimentary tract It is given in doses of 4 gr at intervals of fifteen minutes for two hours and then every half an hour until the stools become green and less copious Kaolin is said to absorb toxins and is administered mixed with water to the consistency of porridge

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SECTION XIX

ADMINISTRATION

CHAPTER LXXVI

THE STRETCHER CASE

IN aerial bombardment an injured person is probably seriously wounded and is certainly suffering from shock. To some of us the word "shock" implies a state of pallid, quiet, almost indifferent prostration in a victim. How different is the picture drawn for us by Dr Trueta Raspall when he describes the patient shocked from injuries during air bombardment as being in a state of "complete mental alertness" and "possessing an acknowledged sensibility". This mental state must make the sufferer apprehensive of any movement, and yet the first handling of many cases vie with the Punch and Judy "Double him up, double him up".

Simplicity must be the keynote. The service must be urgent and pain saving, but above all, it must be rendered confidently in order to establish in the injured and shocked victim trust that carries him or her to the surgeon in no worse plight than need be.

FIGURES 842 AND 843—Trained bearers work in teams of four and the handling is both delicate and precise. Three of the bearers lift the patient whilst the fourth places the stretcher ready under the patient. Note that the patient is held perfectly straight without strain and that the fourth bearer supports his knees whilst being lowered on to the stretcher.

FIGURE 844—**Two-bearer method**—Here is a method whose effectiveness is more knack than brawn. The two bearers face each other and between them lies the stretcher, placed near the injured side of the victim. One bearer turns the patient on to his uninjured side by crossing the leg on the injured side over its fellow and placing the arm over the chest. With one hand on the shoulder and the other on the hip the patient is rolled on to his uninjured side and held there. If a leg is broken the legs are tied together before this manipulation. (*Note*—No. 1 bearer has stood aside to give a good view.)

FIGURE 845—**Two-bearer method**—The other bearer now places the stretcher against the back of the patient, bends over and puts his hand under the shoulder lying on the ground. By resting the patient against the stretcher and allowing it to fall gently to the ground there is the minimum of pulling or twisting.

FIGURE 846—**The Fowler position**—Many cases are more comfortable in Fowler's position, and in chest and abdominal injuries this is *the ideal* position. It is impossible to say how many of the estimated two thirds fatalities in abdominal cases might have been saved by the simple nursing axiom "Fowler's position".

Every ambulance is equipped with two sets of Gooch splinting and

Fig 842

Fig 843

Fig 844 →

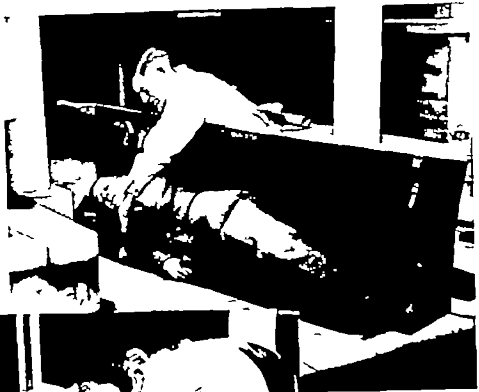

Fig 845 ↓

with Thomas suspension bars These can be utilized to maintain Fowler's position The Cooch splinting is laid so as to protrude nine inches above the bar There is a certain amount of spring in the splinting which adds to the comfort of the patient To prevent the patient slipping on the stretcher a bandage is tied from the upper cross limb of the bar and attached to the patient's trouser buttons or pinned to the underwear it also serves the purpose of keeping the patient from falling sideways

FIGURE 847—**The Fowler position**—Providing the splint is laid properly on the bar the standard ambulance will admit a case on the stretcher in this position

FIGURE 848—**Spinal injuries**—Spinal injuries are a problem to the ordinary

FIG 846

FIG 847

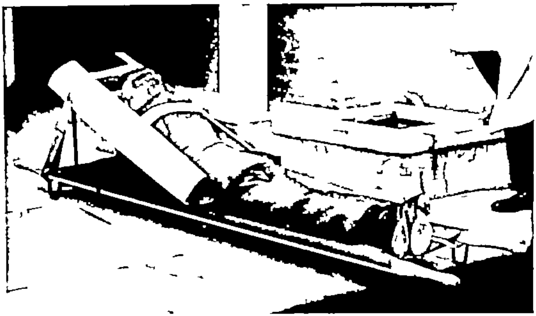

FIG 848

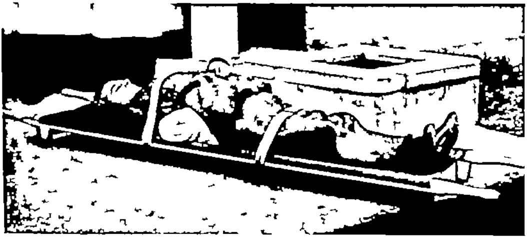

FIG 849

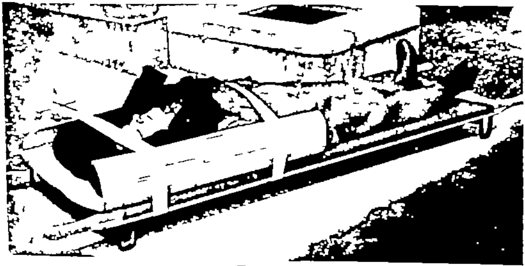

FIG 850

stretcher-bearer He vaguely knows of the danger, and his hesitancy conveys to the victim added doubts and dreads

Lumbar and dorsal spinal injuries—My own opinion is that cases of lumbar and dorsal spinal injuries are best rolled over on to the face, lifted face downwards and placed on the stretcher with the shoulders raised on some support, or blankets

FIG 851

FIGURE 849—**Lumbar and dorsal spinal injuries**—This is the wrong position The patient lying on his back with a blanket under him is certainly less comfortable than in the position shown in Fig 848, and it is a problem to keep him on the stretcher

FIGURE 850—**Cervical region spinal injuries**—These patients are best laid with the support under the shoulders to hyperextend the neck, but there must be a steadying pad on either side of the head This is best secured with a roll of Gooch splinting, as shown

FIGURE 831—This is the wrong method ere the bearers stagger to the stretcher in this position one of them may end up on the stretcher before the patient

Vomiting is a further problem The patient should be propped up in the Fowler s position and provided with a towel to collect the material vomited

Once on the stretcher there should be a reasonable guarantee that the patient will remain there After a raid there may be obstacles for the bearers and ambulance to negotiate The chances of travelling over stones from collapsed buildings and having to use badly surfaced roads or by ways demand that all serious cases be tied to the stretcher

CHAPTER LXXVII

WOUNDS IN NAVAL ACTION

UNDER this comprehensive heading a diversity of injuries must be considered The magnetic mine, the high-explosive shell and bomb, the incendiary bomb and bullet, all add their quota to the wounds of modern naval warfare At the same time, the fittings and architecture of a warship, when damaged, may augment or modify these injuries Thus a shattered deck or bulkhead liberates fragments which cause lacerated wounds and compound fractures, while burst steam-pipes are responsible for extensive burns and scalds Carbon-dioxide poisoning may result from the bursting of a refrigerating plant

The following is an actual list of injuries sustained recently in one of H M ships as a result of enemy action —

1 Shock, concussion and oil-fuel poisoning
2 Contusion of chest
3 Wound of head, abrasion of scalp and chin
4 Lacerated wound of face
5 Lacerated wound of wrist
6 Bruises buttock and thighs
7 Concussion, lacerated wound occiput, hæmatoma right biceps
8 Lacerated wound right heel Contusion right thorax
9 Fractured cervical spine
10 Lacerated wound abdominal wall
11 Lacerated scalp Concussion
12 Contusion left shoulder Concussion
13 Multiple wounds Contusion sacrum
14 Fracture left scaphoid Compound fracture right femur
15 Multiple wounds, fracture coccyx
16 Fracture 4, 5 and 6 right ribs
17 Laceration of penis Contusion testicle
18 Compound fracture left tibia and fibula
19 Laceration face Second degree scald left hand
20 Laceration right buttock Compound fracture left ankle Burn face
21 Extensive burn face and laceration
22 Compound fracture right tibia and fibula
23 Burn face and hands Laceration face
24 Burn face and hands Laceration scalp
25 Burn face Laceration scalp Compound fracture left ankle
26 Burn neck Fractured pelvis
27 Lacerated wound left thigh Compound fracture right femur

MEDICAL ORGANIZATION

General—The success of the treatment of casualties depends to a large extent on efficient prearranged organization From the viewpoint of medical administration, ships are divided into fore and after divisions, in each of which is a previously selected site known respectively as *the forward and after medical distributing station* To these stations casualties are brought from the part of the ship concerned Urgent surgical treatment is carried out in the distributing stations Later, casualties may receive further treatment at a centre known as the *main treatment centre,* which may be located in the sick-bay or the wardroom Thence casualties are evacuated from the ship to shore treatment centres and hospital

Owing to the possibility of damage to the sick-bay or distributing stations, it is essential to arrange previously for alternative treatment centres in wardrooms, messes or cabins

Personnel—A percentage of the ship's company must be trained as stretcher bearers and in first-aid methods. When a prolonged action is in progress, or in ships where only one medical officer is borne, or in the event of the medical personnel being casualties, the captain may approve of selected responsible officers being in possession of supplies of morphia. These officers should previously have been instructed in its administration.

Blood donors—It is a sound practice to have called for volunteers as blood donors. These should be blood typed at the laboratory of one of the naval hospitals.

Equipment—STRETCHERS—An adequate supply of stretchers, especially

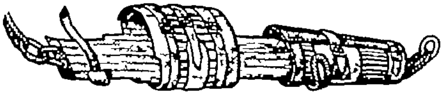

FIG. 832
The Neil Robertson stretcher

of the Neil Robertson pattern, should be stored at convenient sites in the ship. The Neil Robertson stretcher is most useful. It is made of canvas reinforced with split bamboo on the principle of Gooch splinting (Fig. 832). It is light and strong, and encloses the patient (Fig. 833).

SPLINTS—Useful splints to have immediately available are:—

Long Liston
Box splints
Thomas' knee splint
Litler-Jones arm splint

FIRST AID BOXES should be distributed throughout the ship on the various mess decks, in engine and boiler rooms, on the bridge, etc. These boxes must contain tourniquets, bandages, lint, iodine and some burn dressings such as tannic acid jelly or nicalgine. The important consideration is that these boxes should not be locked, but rather have a simple quick release mechanism which cannot get out of order.

HAVERSACKS FILLED WITH FIRST AID REQUISITES are allotted to each gun's crew.

INTRAVENOUS SALINE AND GLUCOSE—Flasks containing sterile saline and glucose, together with the necessary attachments ready for use, should be available in the main treatment centre. If possible, similar flasks containing blood plasma should be provided.

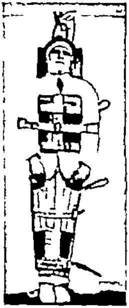

FIG. 833
A Neil-Robertson stretcher in use
(*Brit. Journal of Surgery.*)

RADIANT HEAT CRADLES are easily manufactured on board and several should be available in the main treatment centres.

CHAPTER LXXVII

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Owing to the possibility of damage to the sick-bay or distributing stations it is essential to arrange previously for alternative treatment centres in wardrooms messes or cabins

medical officers It resembles the ordinary record syringe but is conveniently carried in a metal container filled with rectified spirit

After the injection the syringe with needle attached is inserted into the spirit container where it remains sterilized in readiness for further use

In these circumstances of ultra-emergency there is no time to sterilize syringes and to dissolve tablets For these reasons

1 Morphia in solution is issued in 1-oz bottles covered with a rubber cap (Fig 856) A good rule is to have the solution issued in such a strength that 5 minims $= \frac{1}{8}$ gr
2 Those competent in administering the drug are provided with the Wildey pattern hypodermic syringe

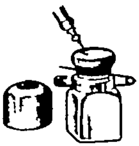

Fig 856

One-ounce bottle of morphia solution with rubber cap and safety pin for attaching to the coat

While overdose must be avoided in general large doses are required in naval emergency surgery i e about $\frac{1}{4}$ gr When a very rapid effect is indicated $\frac{1}{4}$ gr $= 7\frac{1}{2}$ minims (0 5 c c) of the solution can be given intravenously

It is highly important that when an injection of morphia has been given a label should be affixed to the casualty stating the time of the administration and the dose administered As pointed out on page 43 labels may become detached consequently it is an excellent practice to have organized that some prearranged symbol should be marked say on the patient s forehead

Compound fractures—The wound is covered with the service field dressing and as soon as possible an appropriate splint is applied

Burns and scalds—Surgeon Rear Admiral Wakeley recommends that the clothing should be removed or cut away and the whole burnt area be covered with a thick layer of gauze soaked in 1 per cent aqueous solution of gentian violet or 2 per cent tannic acid If these are not available tannic acid jelly tannafax or nicalgine may be used but these cause more pain

(b) IMMEDIATELY AFTER THE ACTION

Casualties must be removed as quickly as possible to the distributing station where they can rest and be away from noise and bustle The Neil Robertson stretcher is used for lowering a patient from a height *e.g* superstructure or for bringing him up from the engine-room or stokehold (Fig 857) Hot water bottles blankets and rugs should be in readiness

Symptoms of shock manifest themselves soon after the injury The patient may be confused mentally but more usually he answers questions rationally and appears to be alert in mind Sometimes with rest and warmth improvement results

If the patient can drink and is not an abdominal case he should be encouraged to do so Warm sweet tea is the best To compensate for loss of body sodium chloride all drinks should contain half a teaspoonful of common salt to a pint Dehydration may be compensated for also by

Again it is emphasized that the medical officer in charge should ensure that his eggs are not all in one basket It is essential to divide up the medical stores and place them at convenient sites permitting of easy access in various parts of the ship This applies particularly to supplies of morphia and anæsthetics Thus if one part of the ship is wrecked he will guard against the catastrophe of losing vital medical stores

TREATMENT OF CASUALTIES

Opportunities for treatment fall sharply into three categories —

(a) During a lull in action
(b) Immediately after the action
(c) More remotely after the action

(a) DURING A LULL IN ACTION

A warship in action is primarily a floating gun-platform and nothing, not even attention to casualties, must be allowed to interfere with or to reduce the rate of fire From the viewpoint of fighting efficiency all casualties are an encumbrance, and attention can only be devoted to them during a lull in, or after, the action

Administration of morphia—As a rule the first essential is to administer morphia to the wounded man where he lies

Morphine lamellæ, for oral administration, have not been found satisfactory When a man, badly wounded, is groaning or restless with pain, it may be difficult to make him retain the lamellæ in his mouth , in cases of injury to mouth or jaw it will be useless Absorption from the stomach is variable and unsatisfactory in severely shocked cases with feeble circulation, hence oral administration is unreliable

The only effective way of administering morphia is by injection

THE WILDEY PATTERN OF HYPODERMIC SYRINGE is an all-steel syringe contained in a metal scabbard to which is attached a safety-pin (Fig 854), so that the instrument may be fixed to the surgeon's coat (Fig 855) A syringe manufactured by Messrs Britton, Malcolm & Waymark Ltd , London, has found favour with naval

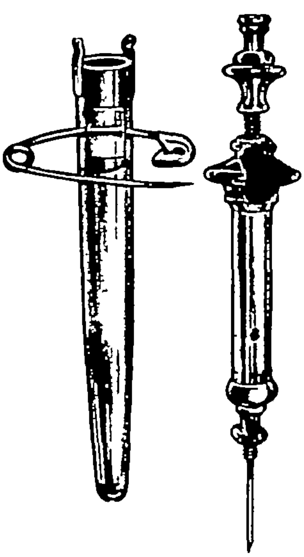

FIG 854
The Wildey pattern hypodermic syringe and scabbard container

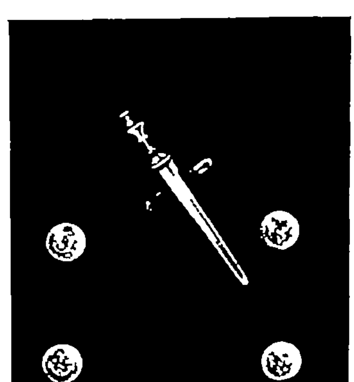

FIG 855
Note the angle at which the Wildey syringe is attached to the coat

and much judgment is necessary in selecting cases for more formal operations It is necessary to discriminate between doing too much on board and doing too little For example if there will be a delay of more than eight hours in evacuating the patient wounds must be excised

FIG 858

A main treatment centre The sick bay H.M S Rodney

SUMMARY

Procedure may be summarized thus —

1 Localization of casualties and application of first aid
2 Preparation of casualties for immediate removal to a previously selected part of the ship This includes arrest of severe hæmorrhage giving morphia and if necessary application of essential splinting
3 Removal of casualties *e g* placing casualties in Neil Robertson stretchers and carrying them from stokeholds engine rooms etc
4 Preliminary examination of casualties and grading them into urgent and non urgent cases
5 Treatment of shock
6 Application of urgent emergency surgery
7 Putting into effect arrangements for the conveyance of casualties from the ship to ambulances for their discharge to hospitals on shore

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administering rectal saline (half a teaspoonful to a pint) in pint doses to supplement oral administration

Isotonic saline and glucose may be given intravenously by drip infusion of about 50 drops per minute While there is interference with respiration, or where there is cyanosis of extremities, oxygen inhalation is useful in the treatment of shock Radiant heat cradles are of proven value No great reliance should be placed upon drugs to raise the blood pressure, but benzedrine (30 mg) or ephedrine (1 to 1½ gr) given intramuscularly is recommended by some

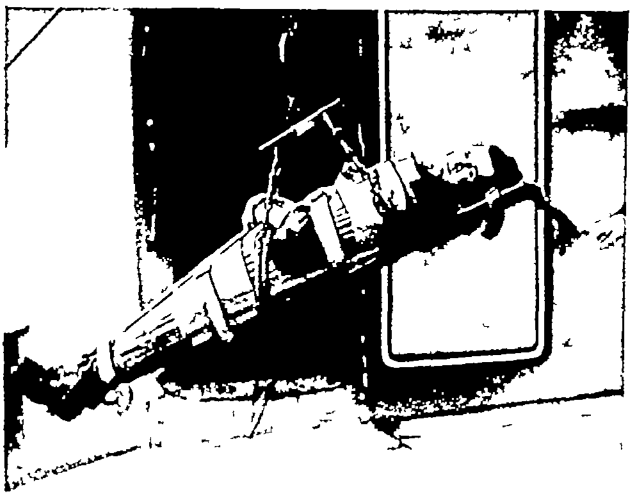


Fig 857
The Neil-Robertson stretcher in stokeholds

When there has been severe hæmorrhage, blood transfusion is of inestimable value Anti-tetanic and anti-gas-gangrene sera must be given to all patients with wounds

Type of work undertaken in the distributing station—In addition to the treatment of shock and hæmorrhage, the rough and ready first-aid treatment can now be supplemented Among other constructive procedures the cleansing and preparation of the skin around wounds and burns can be undertaken with advantage This will save much time when the opportunity arrives for the patient to undergo necessary surgical treatment

Oil-fuel—Owing to bursting of oil-pipes or penetration of oil-tanks by high-explosive fragments, oil-fuel is liberated, and often casualties and their wounds are found to be covered with it The skin surface should be cleansed thoroughly with cotton-waste, and then swabbed over freely with spirit, or ether soap

Anæsthetics—For application and adjustment of splints, evipan or pentothal are excellent Chloroform is also useful as an emergency anæsthetic, but when shock is in evidence ether is preferable

In general, operations should not be carried out while symptoms of shock persist This, of course, does not apply to such life-saving measures as the arrest of hæmorrhage Intestine prolapsed through an abdominal wound should be covered with sterile gauze wrung out in warm saline, no attempt should be made to return it to the abdominal cavity Such a case must wait until a laparotomy can be performed under more favourable circumstances in the main treatment centre (Fig 858)

(c) MORE REMOTELY AFTER THE ACTION

As a general rule it is better that only essential surgical treatment should be carried out in the ship, and, at the earliest possible opportunity, both for psychological and surgical reasons, the patient should be evacuated to a hospital ashore or to a hospital ship Of course, this is not always possible,

ambulance is divided into a headquarters and two companies A headquarters is divisible into a main dressing station and a section which may be detached to operate on its own Each company is divisible into three sections each of which may operate independently This means that seven sections may be evacuating to the main dressing station separately or two three or more may be operating together and the others separately or some may be in reserve ready to proceed forward in an advance or to open up in the rear in case of a withdrawal In the East African campaign with the very long lines of communication the field ambulances not only collected the casualties but with the addition of surgical teams they also formed casualty clearing stations and treated cases in the divisional areas to finality only those cases who could stand long journeys by ambulance cars being sent back to the base In France with a succession of withdrawals the field ambulances in many instances had to act as clearing stations and to hold their cases till arrangements could be made to evacuate patients direct to hospital ships

(c) **Motor ambulance convoy (M.A.C)**—This is a medical transport unit though the medical staff is supplemented with officers and men of the R.A.S.C it is utilized for clearing the sick and wounded from field ambulances to casualty clearing stations and from casualty clearing stations to ambulance trains

(d) **Casualty clearing station (C C S)**—A casualty clearing station is a semi mobile unit designed to receive sick and wounded from field ambulances and also direct from troops in the vicinity

Full surgical treatment of wounded can be carried out here In addition the casualty clearing station can form one or more surgical teams for lending to other formations or can have surgical teams added to it

During quiet periods a certain number of patients who are likely to be fit for duty in a fortnight may be retained for treatment in the casualty clearing station In active operations the wounded arrive in such numbers that the bulk of them must be evacuated at the first opportunity

The casualty clearing station is organized so that a light section may be detached to work by itself or the section may go forward and start taking in casualties until the heavy section arrives later and completes the unit

(e) **Ambulance trains**—Although primarily transport units permanent ambulance trains are staffed and equipped to provide food and treatment during the journey The provision of these trains depends on the distance of the operations from the base

(f) **General hospitals**—These units of 100 200 600 and 1 200 beds are fully equipped and can afford treatment for any kind of disability Normally they are located on the lines of communication and at the base and are grouped together Those at the base are grouped near a port for easy transfer of cases to hospital ships

The 100-bed hospital is mobile and can be moved entirely in its own vehicles from place to place

General hospitals are capable of sending up surgical teams to casualty clearing stations or field ambulances when necessary and when many casualties are being attended to in one place

(g) **Convalescent depots**—When a soldier has recovered from his wounds

CHAPTER LXXVIII

AN OUTLINE OF THE MEDICAL SERVICES OF THE BRITISH ARMY

THE aims of the Medical Services of the British Army have always been the same—to maintain a high standard of health and prevent disease, to care for the sick and wounded, to collect and evacuate the casualties from the field of battle, and to prepare professional records dealing with the health of the army

The methods by which these aims are achieved necessarily change The medical service must keep pace with all the advances of medicine and surgery and in order that the wounded and sick may get the best treatment, arrangements are made to bring them under specialists as soon as possible The increased rate of movement imposed on armies by mechanization while diminishing the time before thorough treatment has greatly increased the distance of evacuation and added many difficulties

The task of dealing with these problems may best be considered under the following headings —

1 The organization of the Medical Services
2 The care of the soldier
3 The history of a casualty

1 ORGANIZATION OF THE MEDICAL SERVICES

(*a*) **Regimental medical establishment**—Each battalion and corresponding unit has its own Regimental Medical Officer (R M O) In peace time and quiet periods in the field he trains the men of his unit in applying their field dressings and lectures to them on first aid Under the Regimental Medical Officer are stretcher-bearers detailed by the unit itself, quite distinct from the bearers of the field ambulance The conditions under which the soldiers live and sleep are closely watched The sanitation of barracks or camps is closely watched, too, and when necessary the Regimental Medical Officer advises his Commanding Officer on any matter connected with the health and fitness of the men In action the Regimental Medical Officer at his regimental aid post attends to the wounded brought to him by the regimental stretcher-bearers

(*b*) **The field ambulance**—The field ambulances are mobile units with a very elastic organization Their primary duty is collection of the sick and wounded from the regimental aid post and their disposal in an area behind the fighting where they may receive early specialist treatment A field

and Army Dental Services and their constant aim is to improve the Army Medical Services and maintain the organization at the highest pitch of efficiency

2. CARE OF THE SOLDIER

Every male British subject of military age is now required to register with the Ministry of Labour Shortly after this he is called up for medical examination The examination is conducted by a Board of five civilian medical practitioners who place him in one of four grades If the man is in Grade 1 it means he is very fit if he is placed in Grade 4 it means that he is unfit for military service After this examination he returns to his employment until called up to a particular unit for training and service as a soldier

The day after his enlistment in his unit he is examined by the Regimental Medical Officer (R M O) who according to his preliminary grading and the R M O s own findings classifies him into a Military Category—A B C D or E Category A means that a man is fit for service in any area in a theatre of war—that is he is placed in a fighting front line category fit to serve at home or abroad A Category B soldier is one fit for employment on the lines of communication base or garrison duties at home or abroad Category C means fit for Home Service only D is temporarily unfit while E is permanently unfit This complicated categorization ensures that a soldier is employed on duties in which his physical state will not be unduly overtaxed

A month after enlistment the soldier is again examined by the Regimental Medical Officer who then has a chance of recategorizing him if necessary and ensuring that training has not brought to light any inherent weakness The Regimental Medical Officer may raise the category of a soldier but a Medical Board of several officers is required to place him in a lower category

During the month and following weeks the soldier is vaccinated inoculated with T.A B a vaccine which protects him against typhoid and paratyphoids A and B and with tetanus toxoid which increases the anti body defence of the blood against tetanus When a man is detailed to proceed to a yellow fever country he is given an inoculation against yellow fever A record of all these inoculations is entered up in the soldier s pay book a document which he carries with him on all occasions

Whilst undergoing recruit training the soldier is seen by the Regimental Medical Officer at intervals and also by the Dental Officer who makes him dentally fit At the end of his recruit training he is again examined before he goes into the field

A number of influences are at work to keep the soldier fit His rations are chosen to give him a balanced diet and the calorie values and vitamin content carefully watched Army cooks now have special courses so that the raw food is properly cooked The Hygiene Department sees to it that the soldier is properly housed that his rooms are capable of thorough ventilation, and that baths are available to ensure personal cleanliness Sanitation of camps is closely watched and in tropical countries steps are taken to minimize the dangers of mosquitoes flies and other pests

When a soldier falls sick or sustains an injury he is sent to a military hospital or a hospital under the Emergency Medical Service where facilities

or illness he is better out of hospital, but is not likely to be fit for duty with his unit until he has had an opportunity of regaining his physical and mental strength, so he is sent to a convalescent depot where he is hardened by graduated exercise and games

(*h*) **Hospital ships**—Hospital ships and hospital carriers convey sick and wounded from base ports to military hospitals outside the theatre of operations

(*j*) **Field hygiene sections**—These units function in divisional areas, lines of communication and at the base They supervise the hygiene and sanitation of their areas and play a large part in the prevention of disease

(*k*) **Mobile hygiene laboratories**—These units are able to carry out extensive investigations of water supplies and analyses of foods

(*l*) **Mobile bacteriological laboratories**—A mobile laboratory is usually located near a casualty clearing station, but it can be moved to any place where outbreaks of disease require investigation The mobile laboratories are for use in the forward areas, each general hospital having a laboratory of its own

(*m*) **Advanced and base depots of medical stores**—All the Regimental Medical Officers and medical units must be kept supplied with dressings and drugs, broken equipment must be changed, and gas cylinders must be refilled This supply is carried out by the advance depots which supply the field units, and the base depots which supply hospitals and also keep up the stocks of the advanced depots

(*n*) **Transfusion units**[1]—These are self-contained units which are fitted with mobile refrigerators for preserving "whole blood," plasma, or serum

In France "whole blood" was flown out to the base and then sent up to the advanced transfusion units which normally functioned with a casualty clearing station They could, however, be detached for use at a field ambulance or general hospital Each unit is in charge of a specially trained Transfusion Officer, who is able to assist in resuscitation wards or operating theatres In addition to "whole blood," plasma and serum are now available for transfusion

(*o*) **Mobile neurosurgical unit**[2]—This unit is designed for use at a centre where head injuries are collected It is mobile and self-contained, and can be attached to a casualty clearing station or hospital in any location

(*p*) In addition to the above, there are special teams for maxillo-facial surgery and chest surgery attached to hospitals especially set aside for cases of that kind

The administration of all these medical units used in the field and all the hospitals and other medical establishments and schools for training in Great Britain is undertaken by the Medical Directorate at the War Office The head of this Directorate is the Director-General, Army Medical Services

The Director-General is represented at the headquarters of forces in the field, at army, command, corps, divisional, lines of communication areas, and base area headquarters

To assist the Director-General there are Directors of Hygiene, Pathology

[1] *Estab*—Officer, 1, R A M C Orderlies, 2, R A S C Driver 1

[2] *Estab*—Surg Spec, 1 Graded Surg, 1, Neurologist, 1, Anaesthetist, 1, G D Officer, 1, Q A I M N S, 2, R A M C Orderlies, 4, R A S C Drivers, 2

operative surgery Plaster of Paris is available too for the closed method of wound treatment A field transfusion unit is attached to each casualty clearing station when it is working but this unit is self contained and can be moved forward to a main dressing station or back to a general hospital if circumstances demand it This unit has supplies of whole blood which may be given to the casualty before during or after operation as required

The casualty clearing station can usually keep a patient until he is fit to proceed by motor ambulance convoy or ambulance train to the general hospitals at the base Here again all the appliances of modern medicine and surgery are available for the benefit of the wounded Medical and surgical specialists ophthalmologists pathologists neurologists and others are available should his case require further investigation and treatment

If the casualty is likely to become fit soon he is kept here till ready for transfer to a convalescent depot and after a period of exercises and a process of hardening he is returned to his unit If his period of recovery and convalescence is to be long he may be admitted directly or if abroad sent back to England by hospital ship or hospital carrier to complete his cure In time he is transferred to a convalescent depot at home and back again to the front

It can be confidently said that no man or woman is better looked after medically than those serving in the British Army

are available for specialist treatment Should his disability be of a mild nature he may be treated in the reception station of his camp or station for two or three days

When the soldier is seriously ill his relatives are informed, and should he become dangerously ill, free travel warrants are granted to two of his relatives to visit him in hospital These warrants are obtained from the local police station

When a Medical Board finds a soldier unfit for further service and the soldier is invalided out of the army, it decides whether the reason for discharge is attributable or not to military service or is aggravated by military service If either is the case the matter goes to the Ministry of Pensions for their consideration and assessment of pension or gratuity

3. HISTORY OF A CASUALTY

A soldier always carries in a small pocket of his battle-dress trousers a first field dressing This is available when he becomes a casualty He applies the dressing himself if he can, or it is applied by those who are near him A very extensive wound may require a larger dressing, and in this case the stretcher-bearers are called forward with their haversacks of larger shell dressings and one of these is applied

The casualty is then sent to the regimental aid post (R A P) to see the Medical Officer He either walks back, is helped back by the stretcher-bearers or is carried back by them on a stretcher At the regimental aid post the casualty will be given fluids, hot sweet tea when possible, and his dressings will be reapplied , if wounded in a limb, the limb may be put at rest on a splint , if necessary, hæmorrhage may be arrested first, morphia can be given, and M & B 693 treatment is in many cases started at this point Details of treatment with dosage and times of administration of such drugs as morphine, etc , are entered on a card attached to the wounded man

From the regimental aid post to the advanced dressing station (A D S) of the field ambulance is the next stage This journey is now done by ambulance car or, occasionally, by stretchers and relays of bearers Here the patient is treated with a view to keeping up his general condition and preventing the onset of shock, and only for reasons of urgent necessity are wounds touched at all Any further doses of morphia or other special treatments are added to his card

The next step in the chain of evacuation is to the main dressing station (M D S) in an ambulance vehicle of the field ambulance Again the casualty's general condition is treated rather than the wound itself Anti-tetanic serum is administered and recorded on the card Here complete details of the soldier are entered in an admission and discharge book, records which are invaluable These records help to compile casualty lists and to trace wounded men

Ambulance cars of a motor ambulance convoy next carry the patient to a casualty clearing station (C.C S) At this unit a surgeon with modern surgical equipment with the help of a specialist in anæsthetics and a radiologist, can give the wounds all the attention demanded by modern

This can be worked out by a formula devised by the late Major-General W Macpherson, which is as follows :—

Let T = Time allowed.
W = Number of sick and wounded.
t = Time taken by a unit of transport for one journey Outwards and return.
M = Units of transport required or available.
N = Number of patients each unit of transport can carry

To ascertain the time required to evacuate a given number of casualties,

$$T = \frac{1}{M} \times \frac{W \times t}{N}$$

To find the amount of transport required to evacuate in a given time,

$$M = \frac{1}{T} \times \frac{W \times t}{N}$$

As an example: It is required to ascertain the time necessary to evacuate 988 stretcher cases and 532 sitting cases over a distance that takes half an hour for the return journey when 18 ambulances are available. The ambulances can carry either 4 stretcher cases or 6 sitting cases.

If we divide our ambulances in the proportion of 12 for stretchers and 6 for sitters, with 988 stretchers at 4 per ambulance = 247 loads, 532 sitters at 6 per ambulance = 89 loads, it will require 21 trips to clear the former and 15 trips for the latter

The time taken will be

$$T = \frac{1}{M} \times \frac{W \times t}{N}$$

(*a*) *For stretchers*—

$$T = \frac{1}{12} \times \frac{988 \times \frac{1}{2}}{4} = \frac{494}{48} = 10 \text{ hours } 20 \text{ minutes.}$$

(*b*) *For sitters*—

$$T = \frac{1}{6} \times \frac{532 \times \frac{1}{2}}{6} = \frac{266}{36} = 7 \text{ hours } 20 \text{ minutes.}$$

As these two evacuations would progress simultaneously the given locality would be clear of casualties by the longer period, namely 10 hours 20 minutes.

10 **Number of vehicles requisite**—These can be ascertained from the estimate of casualties as worked out in accordance with paragraph 6 above plus the time and space factor

Experience has shown that the number of vehicles is greatly under estimated by many lay authorities who have not realized that the speed of motor ambulances with wounded on board is very much less than that of their own private motor cars If sufficient are not provided the scheme is inevitably doomed to disaster

11 **Condition of the casualties**—Some of these will be in a serious condition and their removal to any distance may precipitate catastrophe

The Ministry have issued instructions that serious cases are to be taken direct to hospital without passing through the first-aid post This decision appears to have been based on the conditions prevailing in Barcelona but those in this country are far different The standard of the profession as a whole is much higher in this country than it is in Spain and furthermore a very large proportion of the doctors in charge of first-aid posts have seen active service during the last war and are fully conversant with the treatment of war wounds

Again it is questionable if the first-aid parties are sufficiently skilled to differentiate the serious from the trivial *e g* a splinter entering the abdomen via the buttocks This decision may lead to the hospitals being overwhelmed with slighter cases and to the uneconomical use of ambulances to transport single casualties In my experience many a life was saved in the last war in

standardized throughout the country, but the following will serve as a guide —

(i) Heavy ambulance cars	4 lying or 10 sitting
(ii) Light ambulance cars	2 lying or 3 sitting
(iii) Charabancs	20 to 30 sitting
(iv) Motor omnibuses	45 sitting
(v) Heavy motor lorries	24 sitting, or 8 lying without stretchers, or with stretchers, 3 lying and 4 sitting, or if fitted with frame 6 stretchers
(vi) Light motor lorries	8 sitting, or 3 lying and 2 sitting, without stretchers, or 2 on stretchers with 1 lying case between them
(vii) Converted single decker motor bus (coach ambulance)	10 stretchers

There are many methods of adapting these various vehicles to carry stretchers The official frames supplied by the Ministry can be used or similar frames can be constructed by any carpenter, but the steel scaffolding with its clamps, as used by builders, is one of the easiest ways to adapt any form of transport, from motor buses to railway trucks If additional improvised transport is at all likely to be required in the event of large numbers of casualties, it is essential to have the vehicles earmarked well in advance and to call them up early It is surprising how long it takes for such additional transport to arrive when it is needed, and if this delay is not anticipated, reinforcements are very likely to arrive too late to be of any use

6 **Number of casualties to be transported**—This is one of the most important points in any scheme, for upon an accurate estimate everything depends Not only the number of vehicles required must be worked out in detail, but also personnel, dressings, food and drink, etc

7 **Efficient loading and unloading**—The stretcher-bearers should be taught a "Loading Wagon Drill" which will be found detailed in various first-aid manuals Not only will time be saved if the loading and unloading are performed in a methodical manner, but it will be conducive to the comfort of the patients, who will be spared many a shock that they would experience from clumsy handling, and the time saved will cut short any exposure to the weather

Efficiency in this respect is particularly important when loading ambulance trains Holding up such a train beyond its scheduled time of departure would seriously disorganize other traffic To obviate this the railway authorities may quite possibly start the train before the loading or unloading is finished, valuable space for casualties being lost thereby

8 **Stretcher-bearers**—Stretcher-bearing is most exhausting work, particularly when loading the upper tiers in an ambulance Sufficient bearers for this work are necessary, quite apart from those of the first-aid parties, who may not be on the spot when vehicles are being loaded

9 **Time and space**—A just appreciation of these must enter into any scheme, for upon them and upon the number of casualties the number of vehicles depends, as does also the time taken to clear any locality of a given number of wounded—information frequently required

are held in instant readiness to take the road when ordered. They afford very comfortable passage to the wounded being much more steady and less liable to jolting than are motor ambulances

MOTOR AMBULANCES—If these are required to be added to the convoy they are obtained from the local authority's A R P service in the district concerned Those which are called up will report to the transport officer for orders

MOTOR CARS may sometimes be needed if there are large numbers of sitting cases These too will be called for from the A R.P

MOTOR OMNIBUSES (unaltered) are requisitioned from their owners when necessary It should be realized that these vehicles will be doing their ordinary work or that if they are in garages their drivers are not standing by therefore demands for them must be made in good time lest this transport arrive too late

Handling of the convoy—When the vehicles are assembled they are handled according to the principles set out already Two important considerations are (1) that at either end of their journey there must be good turning space preferably a one way entrance and exit especially for large vehicles (2) that the attendants with each bus must draw from the casualty evacuation train (or the ambulance train) the same amount of equipment as they hand in with their patients If this precaution is neglected the hospital from which the cases came will lose a considerable amount of equipment

The shuttle system described previously is the best *i e* employing single vehicles as opposed to a convoy Supplies of petrol and oil should be available to save the time wasted in returning to garages to refill

THE CASUALTY EVACUATION TRAIN

This differs from the military ambulance train principally in that it can carry a larger proportion of stretcher cases. The former is primarily intended for the transport of casualties occurring through enemy action at home while the latter is designed for the transportation of casualties received at home ports from an expeditionary force, but both types of train will be at the disposal of military and civil defence authorities in case of need

A number of casualty evacuation trains are garaged at various points in the country and are at the disposal of the Regional Hospital Officer for use in his own region. Outside of this, application has to be made to the D G., E.M.S (Movements) These details are further considered below

Capacity—	
Stretcher cases	270
Sitters	40
Personnel—	
Medical officer	1
Trained nurses	3
Assistant nurses and nursing auxiliaries	10
Train orderlies	8
Composition—	
Bogie brake vans (take 30 stretchers each)	9
Saloon coach	1
Bogie third vans (stores and staff)	2

Equipment—These trains are well equipped; among the principal articles are :—

Stretchers	270
Blankets	600
Pillows	160

France by retaining the patient in the advanced dressing station till he had recovered sufficiently from shock to be fit to be moved

12 **Replenishment of medical stores**—Each ambulance, when depositing a patient, must receive from the place of disposal an equal amount of medical equipment to that handed in with the case This refers particularly to blankets, stretchers, splints, hot-water bottles, and the like If this is not done, the stretcher-bearers at the first-aid post will soon be denuded of their equipment and will not be able to function

At each place of reception of patients a dump of these articles should be provided, so that each ambulance attendant can draw from some responsible person the equipment necessary

13 **Switching over**—It has been found that the average casualty hospital cannot take in and " digest " more than 200 patients per diem Arrangements will probably have been made for hospitals to receive casualties in rotation, so ambulance drivers should be familiar with the routes to the various institutions when warned of any change over in reception

14 **The plan**—A concise plan is essential to the successful operation of a transportation service

Before making such a plan it is of great assistance to write what is termed in the army " an appreciation of the situation " Any details that may assist or obstruct or even remotely bear on the problem should be stated The whole should culminate in a plan This appreciation helps us to sort out our ideas and, as it were, crystallizes the essential details

15 **Orders**—Having made our plan, it is necessary to issue orders to our subordinates so that our arrangements may be implemented These again should be short and simple, and, before issue, they should be read by someone other than the writer, so that it is certain that the recipients will be able to understand and also be unable to misinterpret what is desired to be done

Undue verbosity is a serious drawback, and many of the orders, circulars and instructions that the Control receive from the Ministry show this defect An order must be able to be grasped instantly by the recipients, and any lengthy document takes too much time to digest before being acted upon Brevity is therefore imperative

MOTOR AMBULANCE CONVOY (CIVIL DEFENCE)

This is an entirely different organization from the military motor ambulance convoy, and care should be taken not to confuse the two

The civil defence convoy consists principally of converted single-decker motor omnibuses, termed coach ambulances, with lorries and a workshop for maintenance purposes

The civil defence convoy operates under the orders of the regional hospital officer, assisted by a transport officer, and is utilized for evacuating casualties from one hospital to another, usually from casualty hospital to base hospital, either entirely by road or to a casualty evacuation train

Types of vehicle—COACH AMBULANCES are permanently hired from their owners, and their seats are replaced by racks for holding stretchers, of which ten can be carried The vehicles remain in their owners' garages, fully stocked with petrol, oil and equipment, they are driven by their own drivers, and

CHAPTER LXXX

HOSPITAL ORGANIZATION IN THE EMERGENCY MEDICAL SERVICE

THE Emergency Medical Service (E.M.S.) was instituted under the direction of the Minister of Health to provide hospital treatment for casualties[1] both for members of H.M. Forces and for civilians. It was realized that in modern warfare the civilian population would suffer heavily, so the War Office and the Minister of Health agreed that their respective medical resources should be pooled whenever possible, and that no distinction should be made between military and civilian casualties.

At the outbreak of war it was estimated that at least 300 000 hospital beds should be available for casualties. As a result civil hospitals were selected and enrolled, together with their medical staffs, in the Emergency Medical Service. They were classified as follows:—

Class 1A—Hospitals of over fifty beds in which full surgical facilities are available.

Class 1B—Smaller hospitals in which there are good surgical facilities.

Class 2—Hospitals suitable for the treatment of convalescent surgical and chronic medical cases. In certain cases some of these hospitals have been upgraded.

Class 3—Infectious diseases hospitals, which are kept available for their peace-time use.

Special hospitals—Many well-equipped special hospitals are classified between 1 and 2. In some cases, *e.g.* maternity and children's and mental hospitals, they are reserved for their peace-time use.

Annexes to civil hospitals—Many hospitals in dangerous areas have taken over schools and houses in the county to serve as annexes. The parent hospitals are responsible for the administration and staffing of these annexes.

Auxiliary hospitals—In relatively safe areas country houses of a size to accommodate at least fifty beds have been taken over as auxiliary hospitals and convalescent homes. The organization and administration of these is in the hands of the war organization of the British Red Cross and Order of St. John of Jerusalem.

The bed capacity of many E.M.S. hospitals has been increased by putting up extra beds and by the erection of huts and other expedients.

[1] The term "casualty" is defined strictly by the Minister. It includes wounded and sick members of H.M. and Allied Forces (including male and female uniformed members); civilians injured by hostile attack (injured persons taken from ships damaged by enemy action are included); injured Civil Defence Volunteers, if the injury occurs during the performance of their duty; sick children evacuated under the Government Evacuation Scheme; sick transferred from one hospital to another under the E.M.S. scheme; certain other types of civilian sick; and prisoners of war, including interned persons.

together with a certain amount of hospital equipment, medical comforts, dressings, drugs, and instruments Food and domestic stores are replenished locally, and medical stores from stocks held by certain stationmasters

Time and space—As an ordinary double railway line has the capacity, as a rule, of only some twenty-four trains a day, it is essential that no delay in the loading and unloading of trains occur It must be realized that casualty evacuation trains are only a specialized form of railway transport, and that they will have to fit in with the running of other traffic, and that the railway authorities are quite likely to order the train to move at its scheduled time, whether or no the loading or un loading is completed Three to four hours is an average time for loading and unloading a train

Organization—The platforms should be sufficiently long, so that the whole train can be unloaded without moving it Avenues of approach must be such that the ambulances can readily approach and leave A one-way road, which does not involve turning, is essential

Lighting—Since these trains may be used at night, lighting and flares will be necessary, with due regard to black-out regulations

Stretcher-bearers are provided by the St John Ambulance Brigade, the British Red Cross Society, the local A R P organization, other voluntary workers, or troops They must be well trained and there must be sufficient subordinate officials to control them properly A comparatively large number are required, and they should be stationed under control conveniently near the railhead

Entraining is carried out under the instructions of the ambulance officer of the local authority, who should be provided with assistance, preferably by the police, for traffic control He should see that blankets, stretchers, etc , accompanying the patients are replaced from those carried in the train

Detraining—The medical officer of the train will determine the order of clearing each coach and will communicate this order to the detraining officer He will also see that the patients, if in berths, are placed on stretchers by the train staff

The detraining officer, who is appointed by the Regional Hospital Officer, will supervise the detraining The stationmaster selects the platform to be used and excludes the public therefrom Here again replenishment of stretchers must be carried out, equipment being obtained from the evacuating convoy to replace that sent with the casualties it receives

Movement—If a train is required, the County Medical Officer of Health, Borough Medical Officer of Health, or the Group Officer concerned sends his request to the Regional Hospital Officer The latter then requisitions the train through the local railway officer, if in his own region , if in another, through the D G , E M S (Movements) at the Ministry The train is then moved from its shed to its destination by the railway authorities

the purpose of supervising returns, pay and discipline and disposal of Service patients on discharge from hospital. They are responsible also for making arrangements for medical boards on Service patients in hospitals.

Military liaison officers—A senior officer of the R.A.M.C. is posted to the headquarters of Hospital Officers and Group Officers (London Section) to act as liaison officers between the E.M.S. and the Military Authorities.

LOCATION OF HOSPITALS

Whereas from the nature of their work first aid posts and even casualty operating centres with a complement of beds must be situated in areas in which casualties are likely to occur, hospitals themselves should be established away from apparently dangerous areas but should be easily accessible by motor ambulance.

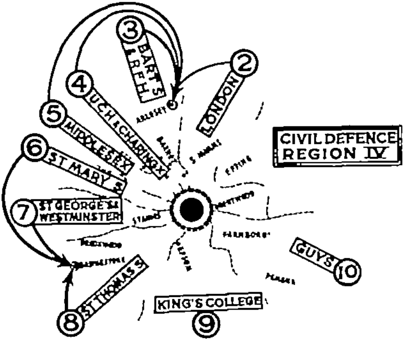


FIG. 859

The London area is divided into ten sectors, the hospitals being staffed by the medical schools indicated.

London, with its big concentration of population, has for hospital purposes been divided into ten sectors each radiating fanwise for thirty or forty miles into the Home Counties (Fig. 859). A nucleus of medical staff and equipment is left at the inner hospitals which act as operating centres for the primary treatment of casualties which may occur in the neighbourhood, the rest being transferred to outer ones. Suitable buildings along the sectors have been converted into casualty hospitals. At the periphery are the base hospitals. In provincial cities somewhat similar plans have been undertaken with regard to individual needs and facilities. In target areas it is advisable to open hospital units outside the town (if these do not exist) where part of the staff and equipment of the casualty hospital is sent. All E.M.S. hospitals should have plans ready for speedy evacuation of part or the whole of the hospital under the supervision of a selected officer. Equipment should

The Government has stated that it will be responsible financially for the cost of maintenance and treatment of civilian casualties as well as Service sick and injured admitted into E M S hospitals

EQUIPMENT OF HOSPITALS

The Ministry of Health has supplied initial medical and surgical equipment on a certain scale to the hospitals which have been upgraded or have been supplied with extra beds for casualties This scale is altered from time to time

Extra beds and bedding, operating theatre equipment and X-ray apparatus have been supplied under these regulations, also antitetanic and other sera, drugs, dressings and splints Some equipment has been supplied from affiliated hospitals, but most of it from central reserves While central purchase has been encouraged in order to reduce cost, in certain circumstances hospital authorities can obtain sanction to purchase perishable goods, such as catheters and rubber gloves

Hospitals have been recommended to keep one month's supply of stores in reserve, turning over the perishable articles each month

Inspection and stocktaking of E M S stores and equipment has to be carried out at least half-yearly by an official of the Ministry If any of it has been lost, or has become defective, other than through fair wear and tear, the fact must be reported

ADMINISTRATIVE OFFICERS OF THE E M S.

Headquarters' Staff—The Minister of Health is the responsible head of the E M S with a medical officer as the Director-General (D G, E M S) There are in addition four directors, assisted by other administrative medical officers It is the duty of certain of these to visit hospitals in order to give medical superintendents such information as they may require A staff of consultants and specialists in the various branches of medicine and surgery is allocated to Headquarters and to the various Regions (*see below*) to advise regarding professional work

Hospital Officers—England and Wales have been divided into eleven regions, principally so that should communications become difficult, Government administration will not be endangered

To each region is allotted a chief administrative medical officer known as the Hospital Officer To his duties of supervising the organization and administration of the E M S in the region is added the administration of the medical branch of the Air Raid Precaution (A R P) scheme

Group Officers—To each of the ten sectors into which the London area has been divided, and to twenty-five of the larger provincial towns in England, and to three in Wales, a Group Officer has been appointed He is generally a member of the senior medical staff of a large hospital in the area In the London areas the Group Officer works directly under one of the directors in the provinces he carries out the orders of the Hospital Officer The Group Officer is responsible for the general hospital organization of his group One of his main concerns is to ensure that a sufficient number of beds for casualties and a sufficient medical staff is constantly available

Senior Medical Officers—In voluntary hospitals there is, as a rule, no medical superintendent Consequently a member of the medical staff should be appointed to act as medical officer in charge He works in conjunction with the lay superintendent

County and County Borough Medical Officers of Health—In addition to their normal duties County and County Borough Medical Officers of Health are responsible for the organization and supervision of the medical services under the A R P scheme They may be requested to act from time to time as agents of the Hospital Officers

Military registrars—To some of the large E M S hospitals or groups of hospitals in which there are likely to be numbers of Service patients, officers, not necessarily medical, have been attached for

Lay staff—The hospital porters engineers and other lay workers will need to be reinforced by local volunteers They should be formed into parties and posted at various points in the hospital for such duties as policing entrances and exits regulating the traffic within the hospital grounds under a competent transport officer unloading ambulances manning lifts and transporting patients within the hospital In teaching hospitals medical students will help in this work Runners to carry messages can be supplied by the local Boy Scout organization Ord suggests that the minimum standards are 18 stretcher bearers and 10 wheeled stretchers per 100 beds

Notice-boards—Entrances exits wards various departments including air raid shelters and the position of fire-fighting appliances should be marked clearly by notice-boards and frequent direction posts should be displayed

Preparation of certain wards—In every casualty hospital certain wards should be designated for special purposes viz resuscitation wards special wards for serious cases after operation and wards for gassed cases In large general hospitals segregation can go further for instance wards can be allocated for chest facio maxillary neurological and ophthalmic cases

Clearing the hospital to receive casualties—In the London area there should be plenty of empty beds for casualties In the provinces where the casualty hospitals are often the county hospitals they may be filled with civilian and military sick If large numbers of casualty beds are required urgently arrangements may have to be made quickly for the partial evacuation of patients Each day a red disc is attached to the bed of every patient who can go home in twenty four to forty-eight hours The Group Officer is notified daily of the number of these patients He will arrange with the Borough or County Transport Officer for their transportation if necessary

If an air raid should occur before evacuation can take place these patients can be kept in the shelters until it is possible to move them and their beds used for the more serious cases

It is advantageous for casualty hospitals to be situated in echelon, so that as one becomes full it can be closed—temporarily—to further admissions and the second one opened. Medical officers in charge of aid posts can be notified from Control of the change The capacity of a hospital for the reception of casualties is determined not so much on the total number of beds as by the number of surgical team and operating and other facilities available. If possible no more casualties should be admitted into any hospital than can be dealt with surgically in a reasonable time, *i.e.*, six to eight hours. If it appears likely that there will be more than this number Control should be asked to send ambulances with further casualties to another hospital If this is not possible, and any hospital is overloaded with wounded, the Group Officer will arrange for the transfer of surgical and resuscitation teams from other hospitals.

Administration—For purposes of administration a casualty hospital can be divided into three sections —

(*a*) Receiving and classification section
(*b*) Treatment section
(*c*) Evacuation section

Whether or not these sections are situated together in one hospital or separated along the lines of communication depends on the situation of the hospital the capacity of the buildings and on the tactical situation The reception section may even be situated in the vulnerable area itself, but the treatment and evacuation sections should be kept farther out

be graded in priority, so that that which is most valuable can be moved first, *e g*, surgical equipment, expensive drugs and X-ray apparatus Hospital authorities when drawing up these plans must decide how much transport will be required This information is forwarded to the Regional Traffic Commissioner

ORGANIZATION OF A CASUALTY HOSPITAL

The Medical Superintendent or the Medical Officer in charge, together with the Secretary, should have drawn up a war plan In war the tactical situation may change rapidly Consequently medical arrangements, while being definite, must also be elastic In the plan should be stated the duties of all, from the senior surgeon to the junior porter Standing orders, kept up to date, should be circulated, and the whole procedure rehearsed several times in conjunction with the A R P services It is only by such forethought that when the emergency arises medical arrangements can be expected to run satisfactorily

After an air raid the function of a casualty hospital is somewhat similar to that of a Casualty Clearing Station (C C S) in the Army medical organization Indeed, should an invasion take place, certain E M S hospitals will undoubtedly become true casualty clearing stations

There is often a first-aid post at the casualty hospital itself This should be a separate entity if possible, with its own one-way entrance and exit for ambulances

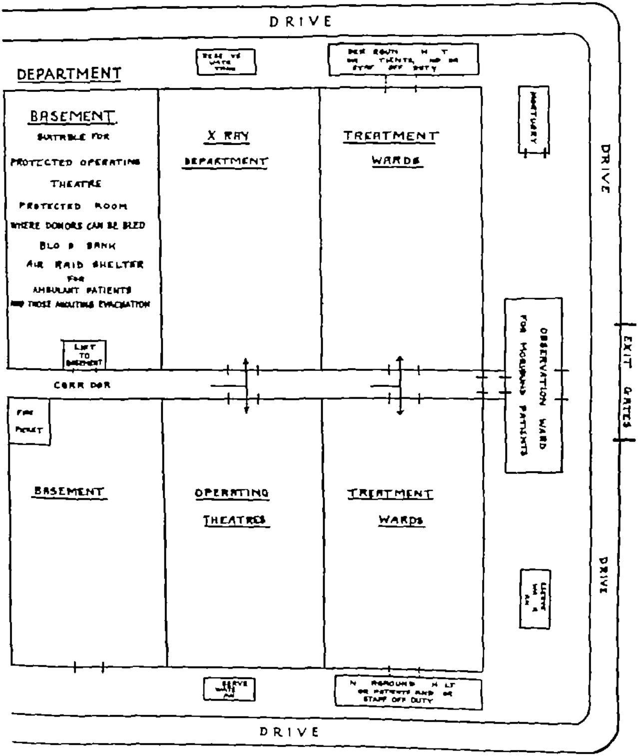
Medical personnel—The surgical staff of a casualty hospital should be formed into teams, each consisting of a surgeon, a house surgeon and an anæsthetist, with a nursing staff Specialists, such as orthopædic surgeons, neurosurgeons, etc , should be retained for their special work Dental surgeons will be needed to co-operate with the surgeons in charge of jaw cases A rota should be drawn up and one or more of these teams, depending on the size and locality of the hospital, should always be on duty

Other members of the staff must be detailed for certain duties and must hold themselves in readiness for duty when a warning has been given There will be the medical officers in charge of the anti-shock treatment, those in charge of wards for gas and moribund cases, the radiologist and his assistants, etc Arrangements should be made for any general practitioners from the neighbourhood who may be available to come to the hospital to act as clinical assistants in the various departments

The Medical Officer in charge, by keeping in touch with the local Control Centre and with the Group Officer, should be able to appreciate approximately the situation regarding the likely number of casualties, consequently, he can make arrangements for accommodation, and for calling on sufficient staff

Nursing staff—The matron, in conjunction with the Senior Medical Officer, will draw up a plan for the nursing staff, which is reinforced from the Civil Nursing Reserve For each theatre the staff should consist of a staff nurse, two nurses and two orderlies If the service of another nurse or clerk is available, she can make notes dictated by the surgeon

In some regions teams consisting of six sisters and nurses who are familiar with acute surgical work have been organized at certain hospitals to reinforce, when necessary, the nursing service of any hospital in the E M S



AND TREATMENT SECTIONS OF A CASUALTY HOSPITAL

FIG 860

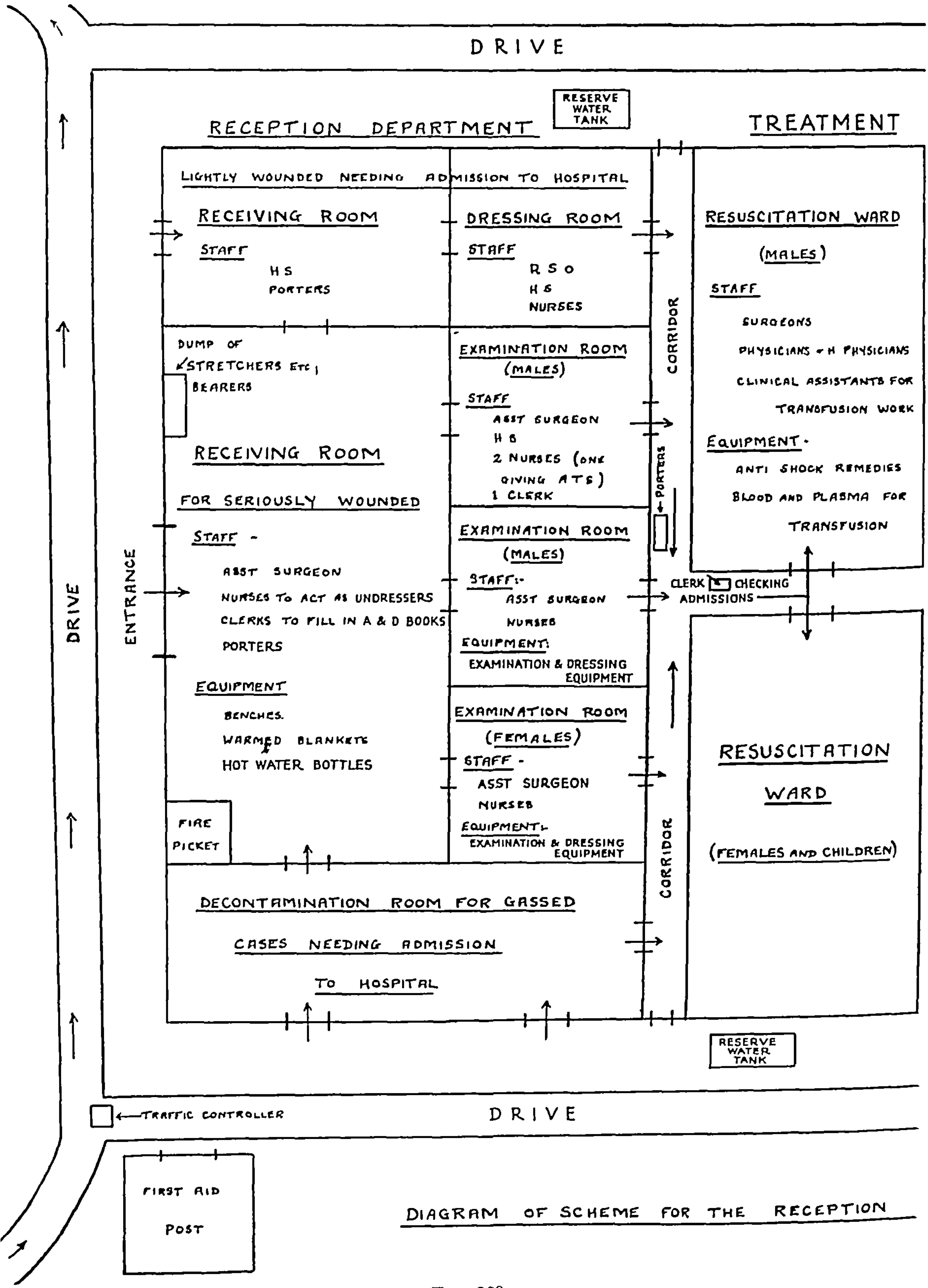

DRIVE
RESERVE WATER TANK
RECEPTION DEPARTMENT
TREATMENT
LIGHTLY WOUNDED NEEDING ADMISSION TO HOSPITAL
RECEIVING ROOM
STAFF
H S
PORTERS
DRESSING ROOM
STAFF
R S O
H S
NURSES
RESUSCITATION WARD
(MALES)
STAFF
SURGEONS
PHYSICIANS + H PHYSICIANS
CLINICAL ASSISTANTS FOR TRANSFUSION WORK
EQUIPMENT -
ANTI SHOCK REMEDIES
BLOOD AND PLASMA FOR TRANSFUSION
CORRIDOR
DUMP OF STRETCHERS ETC; BEARERS
EXAMINATION ROOM
(MALES)
STAFF
ASST SURGEON
H S
2 NURSES (ONE GIVING A T S)
1 CLERK
PORTERS
RECEIVING ROOM
FOR SERIOUSLY WOUNDED
STAFF -
ASST SURGEON
NURSES TO ACT AS UNDRESSERS
CLERKS TO FILL IN A & D BOOKS
PORTERS
EQUIPMENT
BENCHES.
WARMED BLANKETS
HOT WATER BOTTLES
EXAMINATION ROOM
(MALES)
STAFF:-
ASST SURGEON
NURSES
EQUIPMENT:
EXAMINATION & DRESSING EQUIPMENT
CLERK CHECKING ADMISSIONS
ENTRANCE
DRIVE
EXAMINATION ROOM
(FEMALES)
STAFF -
ASST SURGEON
NURSES
EQUIPMENT:-
EXAMINATION & DRESSING EQUIPMENT
RESUSCITATION WARD
(FEMALES AND CHILDREN)
FIRE PICKET
CORRIDOR
DECONTAMINATION ROOM FOR GASSED CASES NEEDING ADMISSION TO HOSPITAL
RESERVE WATER TANK
TRAFFIC CONTROLLER
DRIVE
FIRST AID POST
DIAGRAM OF SCHEME FOR THE RECEPTION

Fig 860

Classification of wounded—The following useful classification of wounded patients is given by Trueta —

1 Those who require early operation and who cannot be evacuated These are dispatched immediately to the resuscitation wards and thence to the operating theatres from a priority list
2 Those who need immediate operation and who can if necessary be evacuated shortly afterwards
3 Those who need immediate treatment for shock but not operation and who cannot be evacuated They are sent to the resuscitation wards
4 Those who need operative treatment but not so urgently They will be sent to the surgical wards
5 Those who need non-operative treatment and who can be evacuated These are sent to the evacuation wards or if possible to their homes
6 Those who are moribund A special ward is set apart for these patients

A coloured label indicating the category should be fastened to each patient

There needs to be the closest co-operation between the surgeon in charge of the classification section and those working in the treatment section The former will draft patients belonging to Groups 1 2 and 4 to the various surgical teams according to the urgency of the case and to the special abilities of the teams

The necessity for extreme gentleness in handling patients many of whom are suffering from shock should be impressed on all.

It has been found that few cases of hysteria come to hospitals as a result of air raids

Patients' personal belongings—These should be placed in Dorothy bags and taken to the wards with the patients Valuables will be taken in charge by a special clerk from the Superintendent s office and later put into a safe Clothes if not too damaged equipment rifles etc will be labelled and placed in the pack store

Clerical work—The clerical work of the reception and classification department is divided into three sections This work can be done quickly and accurately without any delay to the patient but it should be of the simplest character possible All the more detailed returns such as Form E.M S 105 should be completed later

1 Two or more clerks each with a hospital admission and discharge (A and D) book are stationed in the reception hall to take serially the particulars (name address religion nearest relative etc) of incoming casualties Some of this information should be found on the casualty card M.P C 46 if the patient has been through an aid post Nominal rolls of casualties are sent periodically to the Casualty Enquiry Office for the information of the public

2 In the examination room the surgeon as he is examining the patient dictates shortly the clinical findings to a clerk who will enter them on the patient s case sheet The ward to which the patient is to be sent is noted on it together with particulars of the time and amount of antitetanic serum morphia or other drugs which have been given

THE RECEPTION SECTION

In the reception section the wounded are examined and classified, and the need for resuscitation and priority for surgical treatment determined Resuscitation may even be required in those who appear to be only slightly injured, and can be started straight away in this department To prevent congestion and confusion relatives and friends must not be allowed to come in with casualties Accommodation should be reserved for near relatives of those dangerously wounded

The out-patient hall is generally a convenient place for the reception section, provided that it can be suitably warmed and protected The lavatory accommodation for both sexes will generally need enlarging There should be a good road with an easy one-way entrance and exit A handy dump of stretchers, blankets, splints and hot-water bottles under the charge of a porter must be provided for the ambulance orderlies to replace equipment which accompanies their patients A sufficient number of stretcher-bearers should be on duty at the entrance to unload ambulances Should there be an insufficient number, application for reinforcements must be made to the local A R P Control

Equipment—High-backed benches, often to be found in out-patient departments, placed back to back three feet apart make efficient trestles for supporting the stretchers There must be many warmed blankets and mackintosh sheets , hot-water bottles, hot, sweetened, salted tea , gloves and gowns for the surgeons, nurses and assistants , pairs of large scissors for the ' undressers " and bins for soiled clothing Great attention must be paid to the question of heating, as it is difficult on account of doors being frequently opened to keep the temperature of a large hall in winter up to the requisite height

In the examination rooms there should be dressing instruments with an extra supply of artery forceps , tourniquets , dressings , strapping and bandages , a supply of splints , disinfectants, such as euflavine or azochloramine , sulphanilamide, both in tablet and powder form, and insufflators for the latter In each examination room there should be dressing-tables on which are syringes of various sizes, with a plentiful supply of hollow needles , antitetanic serum , bottles of morphia solution, all of the same strength adrenalin , coramine , atropine and hyoscine

As far as possible there should be one-way traffic arrangements for stretchers throughout the hospital

Medical and nursing staff of the reception section—In order that the examination and classification of the wounded can be carried out efficiently, an experienced surgeon with one or more assistants must be in charge The minimum nursing staff will be a sister-in-charge and a staff nurse with two or three nurses In each examination room there is a staff nurse with one or two assistants One is detailed to give tetanus antitoxin to every wounded person who has not had it A number of nursing auxiliaries, working in pairs and armed with large scissors, should be ready to remove part at least of the clothes of wounded patients so that they can be efficiently examined If there is a scarcity of nurses, masseuses who have no fixed duty can be so employed

wards to be carefully watched since even though a priority list for operation has been made the condition may change for the worse and the need for surgical treatment may become urgent If the surgical staff are busy in the theatres and a surgeon cannot be stationed in these wards for this duty the resuscitation officer (who should be a sound clinician) should be responsible for this

Operating theatres—Successful organization of the operating theatres is of paramount importance and no hospital is likely to have too many Additional theatres may have to be improvised beforehand They need not be elaborate—if necessary a ward or hut can be fixed up with the requisite theatre equipment In many theatres a second table can be erected

Operating theatres should be made as safe as possible Some at least should be near the ground sandbagged with windows protected by brick walls Each hospital should have an improvised protected emergency theatre with two or more tables situated in the basement for work during dangerous hours

Special treatment wards—After operation patients should be moved not back to the resuscitation wards for beds there must be kept vacant for fresh casualties but to other wards specially set aside where the necessary after treatment including transfusions can be carried out The less severe cases are admitted to ordinary surgical wards Accommodation should be provided for carrying out dressings and for the application of plaster casts away from the wards In all hospitals dealing with air raid casualties the service of a pathologist should be available for the bacteriological examination of wounds

X ray department—It will very likely be impossible if casualty admissions are at all numerous to X ray all who need it before surgical treatment is undertaken Nevertheless there will be some cases in which this will be imperative A good portable X ray apparatus is essential for all casualty hospitals

Department for the treatment of gas casualties—Preparation must be made in casualty hospitals for the reception of gassed casualties In addition, such patients may have received wounds. A member of the medical staff of each hospital should be selected and specially trained in the organization of such a department and he must train a suitable number of assistants.

A special department will need organizing, with a separate reception room, suitable decontamination rooms and beds in special wards. The reception room should be separate from the main reception station and easily accessible by ambulance Protective clothing is supplied for the staff attending to these patients. Provision must be made for undressing the patients (bins being available for contaminated clothing) and for clothing them in clean pyjamas. Further information concerning equipment required for dealing with gassed casualties and the treatment of these patients will be found in E.M.S. Circular 1 203.

Each hospital holds sufficient equipment for dealing with gas casualties. This includes spectacle frames and B L.B outfits for the giving of oxygen in high concentrations, with a supply of oxygen cylinders for the treatment of a certain number of such casualties. Further equipment, such as scalpels for blood letting, steam kettles, 2 per cent bicarbonate solution for irrigating the eyes and liquid paraffin for instillation dichloramine-T (10 per cent) ointment in a vanishing cream for slight skin burns, saline and triple dye solution or ointment for burns and a solution of morphia should be kept ready

Further supplies of oxygen may be obtained by hospitals (1) from various commercial firms in the town who have supplies—a list has been circulated to hospitals ; (2) from certain hospitals which hold special reserves together with extra equipment (3) from dumps of oxygen cylinders and outfits for the giving of oxygen which have been formed in some towns.

Accommodation for patients' relatives—Accommodation should be set aside for the relatives of patients who are on the special list in order that they can have necessary rest and refreshment

3 The head clerk, stationed at a central position where patients pass on the way to the wards, and near a telephone, keeps the up-to-date bed-state of the whole hospital This must show the number of occupied and vacant beds in all the wards at any given time When a patient leaves the reception department for a ward, his destination is noted on the plan As each patient leaves a ward for the operating theatre or a new ward, the sister in charge of the ward telephones the change and the new destination to this clerk, who will amend the bed-state accordingly Thus at any time an accurate record of the number of empty beds in the hospital can be obtained This information will be sent at frequent intervals if possible to the Group Officer's headquarters during active operations

The Government Statistical Office is undertaking research on wounds and injuries in relation to environment For instance, where was the patient when he was injured? In a particular type of shelter, in a basement, in a building, or in the open? These details in many cases can be obtained by the clerks in the receiving section, and the importance of accurate records must be impressed upon them

TREATMENT DEPARTMENT

Resuscitation wards—Special wards, preferably small, situated near the operating theatres, should be set aside as "resuscitation wards," where patients suffering from wound shock can be thoroughly treated Thus segregated, they can be kept as quiet as possible Postponement of operative treatment until adequate resuscitation has been achieved is imperative In these wards anti-shock remedies must be kept ready These include a plentiful supply of warm blankets and pyjamas, carefully protected hot-water bottles, electric cradles, blood-pressure apparatus and equipment for administering multiple blood and plasma transfusions, also a supply of oxygen cylinders and B L B or spectacle outfits so that oxygen can be given in high concentration A supply of hot, sweetened, salted tea should always be available When a warning is received by the hospital these beds are warmed in preparation

On entering the resuscitation ward the patient comes under the care of the surgeon to whom he has been allocated in the reception room In addition there is a medical officer (generally one of the physicians), with assistants, who is responsible for the estimation and treatment of shock A useful chart on which can be noted the details of the progress of anti-shock treatment has been described by Brittain and Latter Frequent blood-pressure readings should be made and charted

The sisters-in-charge and the nursing staff of these wards should have been specially instructed in the nursing of patients suffering from shock In addition, special nurses who have been trained in blood transfusion should be detailed as assistants to the transfusion officers

Patients are sent to the operating theatres in previously determined order of priority Special notice is taken of those patients on whom a tourniquet has been applied, and these are put forward for operation with a minimum of delay Owing to the extremely dirty condition in which many air-raid casualties arrive at hospital, much cleaning up will be necessary

It is important for the clinical condition of patients in the resuscitation

wards to be carefully watched since even though a priority list for operation has been made the condition may change for the worse and the need for surgical treatment may become urgent If the surgical staff are busy in the theatres and a surgeon cannot be stationed in these wards for this duty the resuscitation officer (who should be a sound clinician) should be responsible for this

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Department for the treatment of gas casualties—Preparation must be made in casualty hospitals for the reception of gassed casualties in addition, such patients may have received wounds. A member of the medical staff of each hospital should be selected and specially trained in the organization of such a department, and he must train a suitable number of assistants.

A special department will need organizing, with a separate reception room, suitable decontamination rooms and beds in special wards. The reception room should be separate from the main reception station and easily accessible by ambulance Protective clothing is supplied for the staff attending to these patients. Provision must be made for undressing the patients (bins being available for contaminated clothing) and for clothing them in clean pyjamas. Further information concerning equipment required for dealing with gassed casualties and the treatment of these patients will be found in E.M.S. Circular 1, 793.

Each hospital holds sufficient equipment for dealing with gas casualties. This includes spectacle frames and B.L.B. outfits for the giving of oxygen in high concentrations, with a supply of oxygen cylinders for the treatment of a certain number of such casualties. Further equipment such as scalpels for blood letting, steam kettles, 2 per cent bicarbonate solution for irrigating the eyes and liquid paraffin for instillation, dichloramine-T (10 per cent.) ointment in a vanishing cream for slight skin burns, saline and triple dye solution or ointment for burns and a solution of morphia should be kept ready

Further supplies of oxygen may be obtained by hospitals (1) from various commercial firms in the town who have supplies—a list has been circulated to hospitals ; (2) from certain hospitals which hold special reserves together with extra equipment ; (3) from dumps of oxygen cylinders and outfits for the giving of oxygen which have been formed in some towns.

Accommodation for patients' relatives—Accommodation should be set aside for the relatives of patients who are on the special list in order that they can have necessary rest and refreshment.

Refreshments, including tea, must be available during active operations for medical, nursing and lay staff

Moribund wards—Special wards should be set aside for patients who are admitted dying and for whom radical treatment offers no prospect of success There they can be nursed in quietness and made as comfortable as possible

Disposal of the dead—There is an official on the staff of the local authorities who is responsible for the collection and, if necessary, for the burial of casualties who have died in hospitals

To further the knowledge of war wounds every endeavour should be made to perform as many post-mortem examinations as possible in the circumstances, and to keep adequate records

Provision of out-patient treatment—There may be a large number of casualties who have received preliminary treatment at a first-aid post yet need out-patient treatment so accommodation and staff must be supplied Some of these patients may need admission to hospital

THE EVACUATION SECTION

To keep beds empty for future casualties, patients should not be retained in casualty hospitals, especially in target areas, for longer than is necessary, they should be moved to base or to special hospitals as soon as they are well enough

In many provincial towns the casualty hospitals, being in most cases general hospitals, may (provided the tactical situation permits) accommodate some patients requiring long-term treatment Arrangements must, however, be made to evacuate these if necessary A number of lightly wounded who may have been admitted into casualty hospitals can be evacuated to an outlying hospital for surgical treatment when daylight arrives

Evacuation is carried out by ambulance convoys or, if the distance is great, by hospital trains which are garaged at certain centres After extensive night bombing it may be impossible to evacuate patients before daylight

THE BASE HOSPITAL

Much of what has been said concerning the casualty hospital applies to base hospitals To these hospitals are transferred casualties for long-term treatment Since streptococcal epidemics are liable to sweep the wards of hospitals treating wounded, arrangements should be made to disinfect the wards periodically by formolizing with blow-pipes and atomizers

Large special centres for the treatment of certain types of injury have been formed, *e g* , for thoracic wounds, orthopædic and ophthalmic injuries neurological cases and for facio-maxillary and plastic surgery Patients suitable for these centres will be evacuated, when fit to travel, under arrangement made by the Group Officer

Theoretically, it might be better to admit suitable patients into a special centre direct from an aid post, provided it was within a reasonable distance In actual practice, however, time might be wasted in sorting out such cases, and a wastage of ambulances would probably result

For the E M S to be a success, hospitals must be prepared to give reciprocal assistance in receiving transferred patients and in sending staff and supplies to those who are in greater need

BLOOD TRANSFUSION SERVICE

Transfusion Centres under the direction of pathologists skilled in blood work have been set up at convenient centres to supply stored blood and plasma to E.M.S hospitals as well as to the services

As a result of public meetings and of periodical advertising in the lay press, the wording of advertisements in such a manner that the public will realize the urgency for volunteers to act as donors and the lack of danger to themselves each group should be able to supply the requisite amount of blood needed The pathological departments of the local hospitals and the Transfusion Centres should be responsible for typing prospective donors bleeding a certain proportion and keeping records Some of the blood carefully labelled with its group and other particulars is kept at the Centre and at hospitals The remainder is sent to the Transfusion Centre for separation of the plasma

Some of the plasma is distributed to hospitals and if the blood bank of any hospital needs replenishing during times of activity the Transfusion Centre will send over supplies of blood or plasma In an emergency after a raid donors on the local list can be called on or in some hospitals suitable patients are typed during their stay in hospital and they will then be available Each casualty hospital however should have a large enough blood bank and should keep it replenished

MOBILE TEAMS

Mobile surgical and resuscitation teams for general and special surgical work have been organized from the staffs of E.M S hospitals Their work may be in their own Sectors and Groups but if called upon by the Group Officer they must be prepared to go to hospitals farther afield

A mobile surgical team consists normally of a surgeon (general or specialized) an anæsthetist a sister with theatre experience and an assistant nurse (or medical student or orderly)

The necessity for the whole of a team to go or to take equipment with it will depend upon circumstances *e.g* it may be needed as a relief or as an addition to the surgical personnel of a hospital Instructions regarding this will be given by the Group Officer The equipment kept in charge of the sister will be supplied by the hospital from which the team is sent The following list which should be regarded as a minimum should be a guide to the requirements of a general surgical team —

Forceps, artery	16	Towel clips	1
" tissue Lane's	4	Razor (with blade if safety)	1
" dissecting	3	Knife, amputation (4 to 5 in. blade)	1
" sterilizer	1	Saw	1
" bone-cutting	1	Periosteal elevator	1
" tongue	1	Gloves (pairs)	6
Scissors	4	Gag	1
Retractors	4	Masks, anæsthetic	2
Volkmann's spoon	1	Drop bottles	2
Needle, aneurysm	1	Needles.	
" holder	1	Ligatures.	
Scalpels or blades	[illegible]	Suture material.	

Additional instruments may be taken at the discretion of the surgeon. A supply of sterilized dressings and a portable table may be necessary

The resuscitation team consists of a medical officer conversant with the methods and an assistant The equipment will include blood plasma, with transfusion outfits, B.L.B inhalation apparatus or spectacle outfit, with cylinders of oxygen

Members of a team will travel in a car belonging to one of its members. They should be in possession of a special certificate supplied by the hospital authorities, so that when on this duty they can move freely in any locality. "Special duty" petrol coupons have been issued to members.

In addition to these teams it may be necessary in an emergency to reinforce certain hospitals by transferring or interchanging medical and nursing personnel In order to perform this speedily, all hospitals keep up-to-date lists of names of their staff who could be spared, temporarily They are allocated for transference for duty to hospitals either in the neighbourhood or in a more distant region which are becoming hard-pressed

PROTECTION OF HOSPITALS

Suitable protection of important units in a hospital, with brick walls, sandbags, wire, etc, has been found to be of value. Local Authorities and governing bodies of hospitals in the E M S should formulate their own proposals for protection in the light of recommendations contained in the Minister's Memorandum No 1 Expert advice can be obtained from architects and engineers of the Ministry or of the Local Authority If approved, financial assistance will be given.

The local Fire Service should be consulted as to the best method of protection of the hospital and also as to what help can be given by this Service in case of fire occurring as a result of incendiary bombs. Fire-watchers should be stationed on the roof in telephonic communication with fire pickets stationed at central points in the hospital Patrols should be about outside during a warning It is advisable to enrol a number of volunteers, some of whom sleep at the hospital each night to be ready to deal with incendiary bombs and fires These, and the rest of the hospital staff, should be trained in fire fighting by officials of the local Fire Service. Fire-fighting appliances, including ladders, should be placed at central points known to all All the top wards of hospitals in target areas should be kept empty.

A trailer fire pump with a squad of trained firemen stationed in the grounds is a valuable acquisition for fire protection of a large hospital As an alternative, the local Fire Brigade may provide a sub-station in the hospital grounds or nearby.

In all hospitals of the E M S X-ray apparatus, blood bank, surgical instruments, dressings and other medical stores should be divided and kept in several departments Particular care should be taken to store inflammable materials, *e g*, X-ray films, ether, etc., in protected places

Several large reserve tanks of water should be provided, and baths and utensils should be filled when a warning is given

During a recent raid the work of a large casualty hospital came almost to a standstill owing to the failure of the electric light through damage to the main by bombs Therefore a large reserve supply of lighting, *e g*, electric lamps run from batteries, hurricane lamps and torches, must be kept ready in each department. The former are by far the best.

The gas supply may fail totally or the pressure may become very low A supply of primus stoves should be obtained

In air raids the telephone system may be disorganized Hospital authorities should obtain two or more volunteers with motor or pedal bicycles (the latter are of more use if roads are damaged) to maintain communication

As roads may easily become impassable owing to damage by bombing and by fallen masonry and as this may be intensified by the black-out ambulances may have difficulty in reaching the hospital indeed some patients may have to be kept at the aid posts until daylight The traffic control will endeavour to open up alternative routes to and from the hospital Therefore the Superintendent must arrange to supply guides who know the new routes for ambulances coming to and departing from the hospital

PROTECTION OF PATIENTS AND STAFF

The black-out of the hospital must be as complete as is humanly possible It has been reported that Nazi airmen prisoners have admitted that if they see a light in their target area they will bomb that locality

Protection of patients and staff in hospitals as well as opportunity for sufficient sleep is of the utmost importance Basements and cellars must be strengthened and adapted with heat and lighting and a sufficient *number of bunks installed If possible dug-outs and shelters should* be made It is better to have a number of shelters so that the patients and staff off duty can be scattered All are told beforehand to which shelter to go When the warning is given patients who can walk are ordered to go to the shelters, care being taken to protect them from the cold. Osborne (1940) has suggested that bedfast patients should be protected by placing a cradle over the head and shoulders and drawing up the bed table to the level of the waist A mattress should be placed over these hanging over the head end of the bed (Fig 861) The object is to avoid so far as possible injury from flying glass and débris and yet prevent the patient from having any sense of suffocation Beds are not moved into the centre of the ward but are left in their usual position though never directly under a window During a raid a ward may be in danger All must be prepared to move these patients If the warning occurs at night the extra nursing staff go to their respective wards and if there is no call for their services they are encouraged to go to bed there

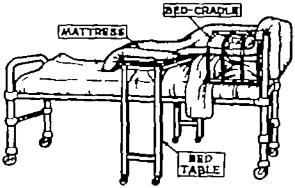

Fig 861
Method of protecting a patient in bed.

All the members of the staff especially those who work in or who may be required to pass through the open during an air raid should be in possession of steel helmets with oilskin curtains and civilian duty respirators

In the event of the hospital being hit, a party of porters or volunteers should be detailed in case of need to help to extricate buried victims, pending the arrival of the A R P rescue squads Suitable tools for this work should be kept in central places

PROTECTION OF RADIUM

It is advisable, owing to the risk of dispersion, that radium should be used only at a hospital in a locality where the risk of a direct hit is almost negligible Radium can be kept safely at hospitals if there is a bore-hole at least 50 ft deep If the hospital is in a district where it is considered justifiable to use radium, patients under treatment should be kept together in a ward near the bore-hole They should not be evacuated whilst under such treatment Only those lesions of a nature in which the radium can be removed easily and quickly should be treated A nurse, competent to remove the radium speedily, should be in charge, with orders that if an air raid warning is received the needles should be removed, checked, placed in a special receptacle and lowered into the bore-hole

[Since this chapter has been passed for press, certain pamphlets relating to E M S hospitals have been issued Where the latter are at variance with the text of this chapter, the pamphlets must be regarded as authoritative —*Author's note*]

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CHAPTER LXXXI

THE ORGANIZATION OF A FIRST-AID POST

ALTHOUGH instructions have been issued by the Ministry of Health, there are many details in the organization which have been evolved by experience but which are not as yet known generally

PERSONNEL

The greatest difficulty is that of personnel If the post is staffed by volunteers it is necessary to have many more on the staff than would be the case if the personnel was paid and on a whole-time basis

In vulnerable areas first-aid posts may have full time paid workers always on duty These form a nucleus for the various services, and in an emergency may be augmented by volunteers. Full-time workers usually consist of —

First-aid parties (men)
Ambulance drivers (men or women).
Car drivers (men or women).
Trained nurses

While volunteers are trained many of them have had little or no practical experience It is therefore a great asset if the services of one or two trained nurses can be obtained Retired nurses and midwives residing in the locality may be prepared to give their services obviously if such professional assistance can be requisitioned it will have a stiffening effect on the amateur staff

It is essential to delegate responsibility the doctor cannot possibly deal with everything at the post This is recognized partially by the appointment of a Depôt Supervisor who is as it were adjutant quarter master and sergeant-major rolled into one

The Depôt Supervisor is a most valuable official and should be chosen with greatest care He should be able to organize the maintenance of the building the supply custody and economical use of medical stores and equipment the keeping of records and the training of staff Above all he must be a person of infinite tact and patience for he will have to arrange times and types of duty for all members—not an easy matter Moreover he must maintain a certain amount of discipline and ensure that the post is ready for instant action Not infrequently he will have to settle disputes and obviate friction—again no easy matter when dealing with a large staff over which he has no authority beyond their willingness to serve In short the Depôt Supervisor must possess the tact of an ambassador the hide of a rhinoceros and the patience of Job A retired army or naval officer or Government official can carry out these duties admirably but he must remember that the staff are volunteers

Assistant officers—Excellent as the Depôt Supervisor s appointment may be it is insufficient Other officers are required for it is quite impossible

In the event of the hospital being hit, a party of porters or volunteers should be detailed in case of need to help to extricate buried victims, pending the arrival of the A R P rescue squads Suitable tools for this work should be kept in central places

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Women

Doctor's table	Nurse	1
	First aid	1
Burns and Slight Dressings	"	2
Eye Table	"	2
Dispenser	"	1
Caterer		1
Driver of car for sitting casualties		1
Ambulance driver		1
Ambulance attendant		1
Telephonist		1
Clerk		1

Decontamination

OUTSIDE—	
Undresser (outer clothing)	1
INSIDE—	
C. 1—Eyes, etc	1
Boots clerk	1
C. 2—Undressers	2
Clerks	[illegible]
Stretcher bearers	2
Showers and Eye Douche	1
Towels and Clothing	1
C. 3—Clerk for disposal	1

The section may require to be duplicated as the post deals with males and females.

COMPOSITION OF FIRST AID PARTIES

Personnel—	
First-aid man	1
Stretcher-bearers	4
Ambulance driver	1
Ambulance attendant	1
Car drivers	2
Vehicles—	
Ambulance	1
Car for sitting cases	1
Car for first-aid party	1
Personal equipment—	
Anti-gas clothing	
Respirator	
Steel helmet	
First-aid haversack	1 large for party
First-aid pouches	4 small
Technical equipment—	
Stretchers	4
Blankets	8
Thomas splint	1
Splints, common	1 set
Mine dressings	4 large
Mine dressings	4 small.
Water bottle	1

First-aid parties should as a general rule be sent out complete (Fig 862) Each member should be in possession of an electric torch, and an indelible pencil for marking the foreheads of patients

Abbreviations to be used —

M Morphia given Dose
T Tourniquet
H Severe hæmorrhage
X Penetrating wounds chest or abdomen
C Gas contamination

for the doctor and the Depôt Supervisor to deal with the hundred and one petty details of administration that arise, particularly in times of pressure Though there is no official sanction for this step, it is recommended that the following should be appointed —

Commandant (men)
Commandant (women)
Section Leaders
Police and Doorguards

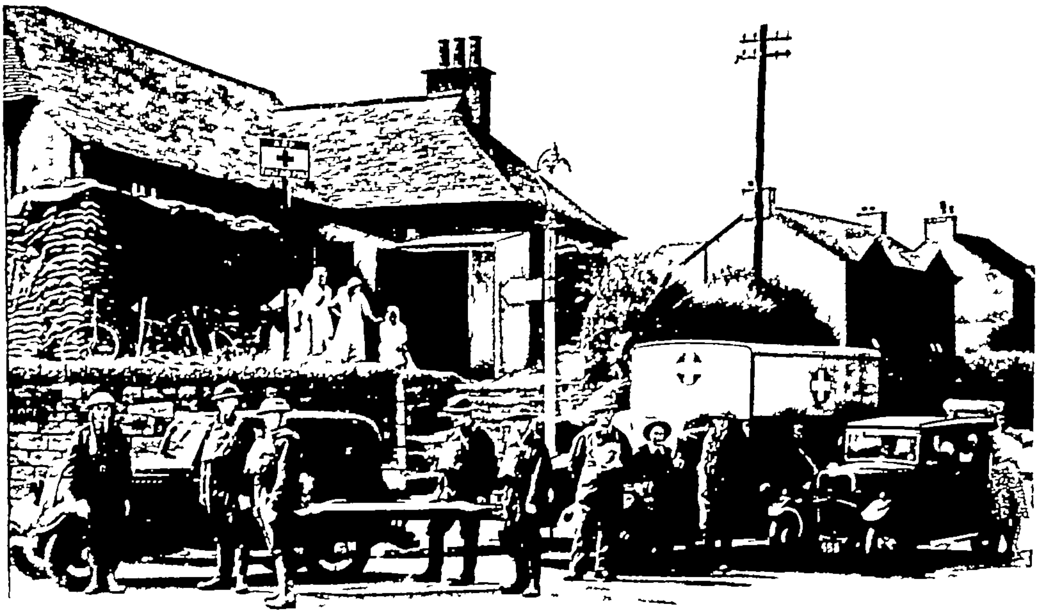

FIG 862
First-aid party in a rural area

This delegation of authority will ensure that the post runs smoothly. These officers should be encouraged to know everyone in their charge, to settle if possible any grievances, and accept and pass on any useful suggestions they may receive They must not forget, however, that the doctor is in charge of the post and that his decision on any matter is final

PLAN OF GENERAL ORGANIZATION

It has been said that a comparatively large number of men and women are necessary to ensure the staffing of the post continually A convenient method of detailing them for duty is by dividing the entire personnel into sections, each under a Section Leader , seven such sections should be instituted, one for each day of the week

COMPOSITION OF SECTIONS

Each section will normally consist of the following —

	Men	
First-aid man in charge		
Stretcher-bearer No 1		
,, ,, 2		
,, ,, 3		
,, ,, 4		Drives own car if possible

Two women, A and B, cover the morning shifts, 6 to 10 A.M. and 10 A.M. to 2 P.M. for instance Section * are on duty—

Sunday	6 to 10 A.M.
Wednesday	10 A.M. to 2 P.M.

The remaining four women, C, D E, F divide the afternoon, evening and night shifts between them; *i.e.*, two women C and D take the afternoon shift, 2 to 6 P.M. two women, E and F the evening shift, 6 to 10 P.M. and all four take duty for the night shift, 10 P.M. to 6 A.M. for instance, Section 2 are on duty—

Thursday	2 to 6 P.M.
Saturday	6 to 10 P.M.
Monday (night)	10 P.M. to 6 A.M. (Tuesday)

An ambulance and a car driver should also be on duty each shift, or if that is not possible, then arrangements made for drivers to report immediately in an emergency

It will be seen that seven telephonists will not be enough to cover all shifts, and in practice the number required is nearer fourteen.

It will be noted also that women allocated to the 6 to 10 A.M. and 10 A.M. to 2 P.M. shifts are only asked to put in eight hours per week. These are usually inconvenient hours for women with household duties, and volunteers for these shifts are not obtained easily

On hearing the raid warning the personnel of the section on duty who are not already at the post should report immediately

STANDING ORDERS FOR FIRST AID POST ORGANIZATION

1 Medical Officer in Charge
2 Depôt Supervisor
3 Secretary
4 Commandant (men)
5 Commandant (women)
6 Section Leaders
7 First-aid Parties
8 Officer in Charge Decontamination Department
9 Deputy in Charge Decontamination Department
10 Nurses
11 Dispenser
12 Telephonists
13 Casualty Clerks
14 Caterer
15 Caretaker

Duties of the above are —

1 **Medical Officer in Charge**—General supervision and attention to serious cases.

2. **Depôt Supervisor**—To act as the second in command of the depôt, and during the absence of the Medical Officer will be in command. The care and maintenance of first-aid post, building and equipment the first-aid party depôt, equipment and vehicles are his responsibility He will consult the Commandant (men) and Commandant (women) when arranging the rota of duties, but should any queries arise the Depôt Supervisor will have the final decision. He will train the ambulance and car personnel, and generally supervise the staff. All correspondence will be dealt with by him, but if possible all out-going letters should be signed by the Medical Officer.

3. **Secretary**—To act as secretary to the Depôt Supervisor and attend to all typing and filing of letters and keeping of accounts. In the event of an air raid she will type forms in triplicate, giving particulars of casualties, and type all messages to officers concerned at the post.

4. **Commandant** (men)—He will be in charge of the stretcher parties, ambulances, cars, and ambulance attendants. On receipt of orders from the Medical Officer or Supervisor he will detail each of the above as he considers necessary for the allotted task. He will detail men to be in charge of air lock doors, who will ensure that one door is closed while the other is open. These guards will also prevent the entrance of unauthorized persons.

The Commandant (men) will notify the Medical Officer or Supervisor immediately if gas is detected. He will assist the Depôt Supervisor in arranging the rota of duties, and will bring to his notice any dissatisfaction with the times arranged.

This will ensure that vital information concerning the cases is brought to the immediate notice of those receiving them

A ROTA OF DUTY

One of the difficulties of manning a first-aid post with part-time volunteers is that men are not usually available immediately in the daytime, consequently during the day the post must be staffed to a large extent by women Most women have their own household duties to attend to, and cannot be expected to do more than three periods of duty per week

The table below shows a convenient method of arranging duties for seven sections Each twenty-four hours is divided into four four-hour day shifts, and one eight-hour night shift

Time	Sunday	Monday	Tuesday	Wed	Thursday	Friday	Saturday
	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 1
6 to 10 A M	Women A B Tel *	Women A B Tel	Women A B Tel	Women A B Tel	Women A B Tel	Women A B Tel	Women A B Tel
	Section 6	Section 7	Section 1	Section 2	Section 3	Section 4	Section 5
10 A M to 2 P M	Women A B Tel	Women A B Tel	Women A B Tel	Women A B Tel	Women A B Tel	Women A B Tel	Women A B Tel
	Section 5	Section 6	Section 7	Section 1	Section 2	Section 3	Section 4
2 to 6 P M	Women C D Tel	Women C D Tel	Women C D Tel	Women C D Tel	Women C D Tel	Women C D Tel	Women C D Tel
	Section 3	Section 4	Section 5	Section 6	Section 7	Section 1	Section 2.
6 to 10 P M	Women E F Tel	Women E F Tel	Women E F Tel	Women E F Tel	Women E F Tel	Women E F Tel	Women E F Tel
	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
10 P M to 6 A M night shift	Women C D E F	Women C D E F	Women C D E F	Women C D E F	Women C D E F	Women C D E F	Women C D E F
One first aid party	Men 1 2 3 4 5	Men 1 2 3 4 5	Men 1 2 3 4 5	Men 1 2 3 4 5	Men 1 2 3 4 5	Men 1 2 3 4 5	Men 1 2 3 4 5

* Telephonist

The above rota is based on a minimum of six first-aid women per section, indicated in the table by the letters A, B, C, D, E, F

To be carried in the vehicle

Blankets		8
Splints, thigh, wooden	sets	3
Straps, webbing, with metal fasteners, for securing splints		21
Stretchers		4
Slings, strong webbing (for carrying stretcher)		2
Hot water bottles		2
Basins, enamelled iron, about 6 in. diameter		2
Respirators, spare if obtainable, for use of casualties whose own are lost or destroyed.		

Stretcher bearers—*It is desirable that all stretcher-bearers should be fully trained first-aid men.* The first-aid man in charge—usually No. 1 stretcher bearer—will attend to the casualty assisted by Nos. 2 and 3, unless they are attending other casualties. No 4 prepares the stretcher and blankets and helps as required.

For loading the stretcher with two or four men see Chapter LXXVI

Loading ambulance—The stretcher should be lowered to the ground in line with the vehicle, the patient s *head* to the *front* After No. 1 or the ambulance attendant has made certain the tracks and steadying straps are clear the four bearers turn inwards, lift the stretcher and slide it into the tracks, assisted, if possible by the ambulance attendant. The upper or more awkward berth should usually be loaded first *Two men alone should never attempt to load or unload an ambulance.*

Should there be more casualties than the vehicle can accommodate at once, the first-aid man in charge will decide priority of removal. Bearers will identify unconscious patients if possible Neighbours or other casualties may be able to supply this information, which will be noted on the casualty card.

On arrival at the post the leader of the party will decide the cases to be unloaded from the ambulance. Casualties will be taken into the reception room or office where the clerks will register names and addresses, etc. After registration the patient is carried into the waiting room. Here the doctor or Commandant (woman) will decide on priority

The above suggestions are not to be taken as a complete guide, and all first-aid party personnel are advised to obtain "Air Raid Precautions Handbook No 10" on the training and work of first-aid parties.

8 **Officer in Charge of the Decontamination Department**—He is responsible for entire control of the department He will look after all equipment and deal with all men casualties. He will also attend to the marking and disposal of contaminated clothing

9 **Deputy in Charge**—She will take charge of women s section and deputize in the control of the department if this is necessary

10 **Nurses**—They will carry out duty in the first-aid room or where required. They will ordinarily be employed on shifts, but on the occasion of an air raid all nurses on hearing the signal will immediately report for duty

11 **Dispenser**—The Dispenser will draw drugs and dressing and other surgical equipment from the Depôt Supervisor

12 **Telephonist**—On receiving a message she will immediately write it out in triplicate on Form A.R.P./M.3 and read it back to the person from whom she has taken it. Her assistant will hand two copies of this message, one to the Depôt Supervisor and one to the Commandant (men). The Commandant (women) will be informed by the Telephonist s assistant.

The Commandant (men) will then detail such stretcher parties, ambulances, cars, and ambulance attendants as he considers necessary to deal with the task.

The Telephonist should use Form A.R.P /M.1 when taking particulars of casualties from the wardens post, and must use the authorized abbreviations.

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On receipt of the air raid warning the Telephonist will at once notify the following —

Medical Officer in Charge Depôt Supervisor Secretary	by telephone.
Commandant (men) Commandant (women) Decontamination Officer	by messenger or telephone

13. **Casualty Clerks**—On admission the clerks will record, in duplicate, the following particulars of each casualty :—

Name.
Age.
Address.
Religion.
Time of admission.
Nature of injury

5 **Commandant (women)**—She will control all nurses and supervise all women voluntary helpers and issue all first-aid equipment She will assist the Depôt Supervisor in arranging the rota of duties, and will bring to his notice any dissatisfaction with the times arranged She will also assist the Depôt Supervisor to check the stock and inform him of the amount used On admission of casualties she will classify them into the following categories —

Slight or serious wounds
Gas or burns

She will use her discretion as to the order in which they will be dealt with in the dressing-room.

6 **Section Leaders and Personnel**—The personnel are divided into seven sections, each of which is under the command of a Section Leader

In order to save the voluntary staff from being requested to do too many hours on duty, the personnel are divided into the above-mentioned seven sections the shifts being arranged as follows .—

One eight-hour night shift
Four four-hour day shifts

The rotas showing to which duties the personnel are allocated will be found on the notice-board.

Application to change the hours of duty as shown on the rota should be made to the respective Commandants

On hearing the raid warning the personnel of the section on duty who are not already at the post should report immediately

The remainder of the sections will stand by ready to join the aid post if and when required. They should, however, report when the 'all clear' has sounded if it is evident that bombs have been dropped in the locality

Owing to the danger of being machine-gunned from the air personnel should take every advantage of any cover on their route The use of electric torches, smoking and the striking of matches show up for a long distance in the dark and will inevitably attract hostile fire

7 **First-aid Parties**—

PERSONNEL AND TRANSPORT—

Ambulance, with driver and ambulance attendant
Car for personnel
Car and driver for sitting casualties
First-aid man in charge
Four stretcher-bearers

EQUIPMENT—Each stretcher-bearer will be issued with a first-aid pouch containing .—

Bandages triangular	9
Dressings, first-aid large	6
Dressings, first-aid, medium	6
Canes for tightening improvised tourniquets (6 in long)	3
Labels casualty identity, books of 20 (with indelible pencil)	1
Ointment bleach, in 2-oz tins (and pieces of clean washed rag)	1
Safety-pins, large, cards of 6	3
Scissors, 7 in, with lanyard (one blade pointed)	1
Tourniquet	1

Each member of a first-aid party will carry a water-bottle and an electric hand-lamp

First-aid parties will also be issued with a first-aid party's haversack (one haversack per party) containing —

Bandages, triangular		36
Canes for tightening improvised tourniquets (6 in long)		8
Clasp-knife large		1
Cotton-wool, 1-oz packets		6
Dressings, first-aid, large		18
Dressings, first-aid, medium		12
Lint, unmedicated, in squares about 8 in by 12 in.		6
Ointment, bleach, in 2-oz tins (and clean washed rags)		4
Safety-pins, large, cards of 6		8
Tourniquets, St John type		2
Tourniquets Samway type		2
Splints sectional wooden	sets	2
Straps, webbing with metal fasteners for securing splints (length about 18 in, width about 2 in)		18
Tannic acid jelly, ½-oz tubes		4
Torch or lamp with stand and shield		

To be carried in the vehicle

Blankets		8
Splints, thigh, wooden	sets	3
Straps, webbing with metal fasteners, for securing splints		21
Stretchers		4
Slings, strong webbing (for carrying stretcher)		2
Hot water bottles		2
Basins, enamelled iron about 6 in. diameter		2
Respirators, spare if obtainable for use of casualties whose own are lost or destroyed.		

Stretcher-bearers—*It is desirable that all stretcher-bearers should be fully trained first-aid men* The first-aid man in charge—usually No. 1 stretcher bearer—will attend to the casualty assisted by Nos. 2 and 3, unless they are attending other casualties. No. 4 prepares the stretcher and blankets and helps as required

For loading the stretcher with two or four men see Chapter LXXVI.

Loading ambulance—The stretcher should be lowered to the ground in line with the vehicle, the patient's *head* to the *front* After No. 1 or the ambulance attendant has made certain the tracks and steadying straps are clear the four bearers turn inwards, lift the stretcher and slide it into the tracks, assisted, if possible by the ambulance attendant. The upper or more awkward berth should usually be loaded first *Two men alone should never attempt to load or unload an ambulance*

Should there be more casualties than the vehicle can accommodate at once, the first-aid man in charge will decide priority of removal. Bearers will identify unconscious patients if possible. Neighbours or other casualties may be able to supply this information, which will be noted on the casualty card.

On arrival at the post the leader of the party will decide the cases to be unloaded from the ambulance Casualties will be taken into the reception room or office where the clerks will register names and addresses, etc. After registration the patient is carried into the waiting room. Here the doctor or Commandant (woman) will decide on priority

The above suggestions are not to be taken as a complete guide and all first-aid party personnel are advised to obtain "Air Raid Precautions Handbook No 10" on the training and work of first-aid parties.

8 **Officer in Charge of the Decontamination Department**—He is responsible for entire control of the department He will look after all equipment and deal with all men casualties. He will also attend to the marking and disposal of contaminated clothing

9 **Deputy in Charge**—She will take charge of women's section and deputise in the control of the department if this is necessary

10 **Nurses**—They will carry out duty in the first-aid room or where required. They will ordinarily be employed on shifts, but on the occasion of an air raid all nurses on hearing the signal will immediately report for duty

11 **Dispenser**—The Dispenser will draw drugs and dressing and other surgical equipment from the Depôt Supervisor

12 **Telephonist**—On receiving a message she will immediately write it out in triplicate on Form A.R.P./M.3 and read it back to the person from whom she has taken it. Her assistant will hand two copies of this message one to the Depôt Supervisor and one to the Commandant (men) The Commandant (women) will be informed by the Telephonist's assistant.

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13. **Casualty Clerks**—On admission the clerks will record, in duplicate the following particulars of each casualty :—

Name.
Age.
Address.
Religion.
Time of admission.
Nature of injury

On the discharge of patients the clerk will enter the destination (hospital or home) to which the patient has been sent, the time of discharge, and whether the patient is to report for further treatment

14 **Caterer**—He will ensure that a supply of tea and sandwiches is always available As these commodities are not a public supply, the caterer should obtain the necessary materials from those willing to give them

15 **Caretaker**—He will be responsible for the cleaning and heating of the building, and must attend to the black-out arrangements He must report for duty immediately he hears the air-raid warning

FILLING IN OF FORMS

On completion of treatment at the first-aid post particulars must be entered on the casualty form These particulars will include the destination of the patient The casualty clerk in the exit collects, verifies and returns the forms to the office The clerk must also fill in casualty card M P C 46 in respect of any patient transferred to hospital

The Ministry of Pensions require Form M P C 44 to be completed showing the particulars of casualties treated at the post for each raid In order that this form may be compiled it will be convenient to make out a case sheet for each casualty On this sheet the admission clerk will note the following —

Date
Serial No (of casualty)
Name
Age
Address
Religion
Nature of injury.

One copy of the above will be sent in to the first-aid room with the casualty, and the evacuation clerk will note down the nature of injury and disposal, *i e*, whether sent to hospital or patient's home, etc

SECTION XX

APPENDIX

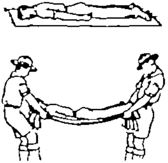
CHAPTER LXXXII

APPENDIX

In this, the final chapter I will attempt to supplement omissions and to review the literature which has appeared while the work was in progress but has not been directly referred to in the text. The disproportion between the enormity of this task and the space available has made it necessary to confine my remarks to features having definite practical value.

FIRST AID

Recent literature abounds in comments on the dangers and futility of the indiscriminate application of tourniquets by first-aid workers. The general consensus of opinion seems to be that a time has been reached when the tourniquet should be removed from first aid equipment and the first aid worker taught to apply a dressing and a firm bandage and to elevate the limb.



FIGS 863, 864 Transporting a patient with a fractured spine

There is still need to emphasize to first aid workers the necessity of the face-downward method of transporting patients with a fractured spine. The accompanying diagrams (Figs 863 and 864) are modified from instructions given to American Boy Scouts (H F Hodges and E B Crogono) [1]

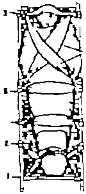


FIG 865 Securing a patient to a stretcher with seven triangular bandages. They are applied in the order enumerated.

An excellent method of securing a patient to a stretcher [2] is illustrated in Fig 865. Seven triangular bandages are employed and they are applied in the order shown.

W G Morden [3] has designed a support for a Thomas splint to be used in conjunction with a stretcher (Fig 866).

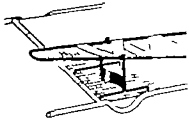


FIG 866 Morden's support for a Thomas splint whilst the patient is on a stretcher

G Henschen [4] has found a sterile safety pin can be utilized to great advantage in the forward zone. In wounds of the floor of the mouth in which the middle of the mandible has been shot away he passes a safety pin vertically through the tongue, places it vertically in front of the lips and maintains it there by tape passed through the eye of the

Henderson, M. S. *Collected Papers Mayo Clin.*, 1940, 32, 81.
Hodges, H. F., and Crogono, E. B. *Lancet*, 1941, 1, 2-9
Morden, W. G. *Lancet*, 1941, 2, 440
[4] Henschen, O. *Schweiz Med Wchnschr.*, 1940, 2, 711.

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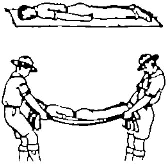

Figs. 863, 864

Transporting a patient with a fractured spine

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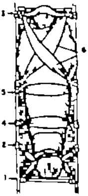

Fig 865

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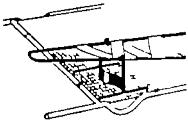

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[4] Henschen, G *Schweiz Med Wchnschr*, 1940, 2, 711.

safety-pin and passed behind the ears and tied at the back of the head (Fig 867) In cases of open pneumo-thorax he fixes the lung to the thoracic wall by safety-pins He also recommends that a wound of the intestine should be closed provisionally or eviscerated bowel anchored to the skin by the same means

Fig 867

Safety-pin method of keeping the tongue forward when the mandible has been shot away

J H Gunter [1] says in extensive wounds of the face the best *emergency treatment is to tack the skin to the* mucous membrane across the raw surfaces If this is done, the work of the plastic surgeon will be greatly facilitated

R H Ivy and R A Stout [2] describe an emergency apparatus made from wooden tongue depressors, adhesive plaster and a bandage, to be used if there is backward displacement of either the upper or the lower jaw interfering with respiration An elastic band can be attached to this apparatus (Fig 868) and to either the upper or the lower teeth, and constant traction will be maintained

Fig 868

Ivy and Stout's emergency method of maintaining forward traction of either the upper or lower jaw

In many cases of gunshot wounds of the neck, immediate tracheotomy is necessary If a tracheotomy tube is not available, a large-size rubber catheter can be fashioned as a substitute (G M Blech) [3]

S W Harrington,[4] speaking of the first aid treatment of open wounds of the abdomen, with evisceration, says that the common advice is not to replace the intestine in the abdomen He agrees that if there is evisceration with leakage, it is best not to replace the coils in the abdomen, but if there is no leakage, and there is no obvious contamination, and the distance through which the patient must be transported is comparatively great, replacement is advisable

Artificial respiration—G Bates [5] *et al* quote an example where artificial respiration was continued for eight hours before the patient was saved This was in a case of electric shock Bates suggests that if artificial respiration is commenced within one minute of an electric shock 90 per cent of patients recover When there is a delay of six minutes, only 10 per cent of patients are capable of being resuscitated

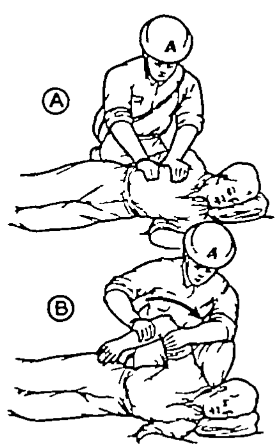

Fig 869

The Copenhagen method of performing artificial respiration

The ROWING METHOD is claimed by M C Rosekrans [6] to be the best of all With the patient supine, the first-aid worker places himself at the patient's head The patient's arms are grasped at the wrists and firmly extended above his head to raise the chest They are kept in this position long enough for air to enter the chest, and then rapidly dropped back towards his chest, leaving them there long enough for air to rush out of the chest This rowing motion is repeated ten to twelve times per minute

THE COPENHAGEN METHOD [7]—The patient is placed on his left side with his head supported on a cushion or folded coat, and the left arm and left leg moderately flexed to give support Expiration

[1] Gunter J H *Military Surgeon*, 1940, 88, 375 [2] Ivy, R H, and Stout, R A *Ann Surg*, 1941, **113**, 1001
[3] Blech, G M *Military Surgeon*, 1940, 88, 387
[4] Harrington, S W *Proc Staff Meet Mayo Clinic* 1940, 15, 805
[5] Bates, G, *et al* *Canad Med Ass Jour*, 1938 39 120
[6] Rosekrans, M C *Wisconsin Med Jour*, 1941, 40, 567 [7] Praest, P *Acta Med Scand*, 1940, **103**, 539

is effected by lateral pressure of both hands on the lateral aspect of the thorax (Fig 889 (A)), and inspiration by drawing the patient's right humerus upwards and backwards (Fig 889 (B)). [From the theoretical consideration the main difficulty would appear to be in maintaining the lateral position unless intelligent help is available —H. B]

Thirst at sea—Morley Roberts in 1910 conceived the idea that when no fresh water could be obtained death at sea from thirst could be at any rate postponed by rectal injections of sea water[1] He recommended that a Higginson's syringe should form part of the ship's lifeboat equipment Wherry independently suggested slow gravitation of sea water into the lower bowel by a funnel and tube Has this seemingly cardinal observation been put to a practical test ?

Snake bites—According to J W Pender[2] the first aid treatment for a bite from a poisonous snake is to make a criss-cross incision of about half an inch through each fang mark The incisions must go well through the skin to allow free bleeding Suction is applied In the absence of a breast pump a bottle should be taken and a small piece of paper burnt therein Before the flame is extinguished the mouth of the bottle is applied tightly over the wound In event of no bottle being available the wound is sucked with the mouth As the swelling spreads a ring of criss-cross incisions is made in the swollen area 2 in from the primary incision Suction is applied to these wounds for fifteen minutes of each hour for fifteen hours Pain is severe and shock must be combated continually If the patient can be tided over twenty four hours there is hope

Human bites—T M Lowry[3] is surgeon to the Beekman Hospital, situated near the water front of New York City and he has analysed nearly 200 cases of human bites At his hospital many forms of treatment have been tried these include excision of the wound sulphonamide therapy and the administration of salvarsan preparations on the assumption that Vincent's organism was the main infecting agent None of these have proved so satisfactory as early chemical cauterization His advice is that all human bites should be cauterized with fuming nitric acid Subsequent local treatment should be conservative The involved part should be immobilized and chlorine bearing solutions are the most valuable of all local dressings

MECHANIZED WARFARE HAS CHANGED CONCEPTIONS OF FIRST AID

In the 1914-18 war a regimental surgeon's aim was to apply such surgical measures as would enable the wounded to be evacuated to the rear Too often in modern mechanized warfare there is no rear Obviously under such circumstances it is useless for instance to apply a tourniquet and Von Bergmann's dictum that in the front line a student of theology was more valuable than a professor of surgery becomes obsolete The modern regimental surgeon must be prepared to ligate arteries (85 per cent of deaths on the battlefield are due to hæmorrhage J H Gunter[4]) and to perform other desperately urgent emergency operations The morale of the troops depends on facilities being afforded him to do so

The chapter on the Organization of a Field Ambulance included in the

[1] Annotation, *Brit Med Jour.*, 1941 2, 126
[2] Pender J W *Collected Papers, M yo Cl* 1940 32, 67
[3] Lowry T M *Surg Clin. North Amer.*, 1941 21, 563.
[4] Gunter J H. *Military Surgeon* 1940 86, 373

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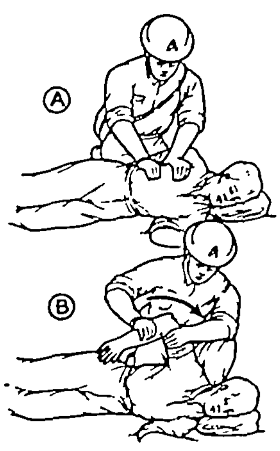

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[4] Harrington, S W *Proc Staff Meet Mayo Clinic* 1940, **15**, 808
[5] Bates, G, *et al* *Canad Med Ass Jour*, 1938, **39**, 120
[6] Rosekrans, M C *Wisconsin Med Jour*, 1941, **40**, 567 [7] Praest, P *Acta Med Scand*, 1940, **103**, 530

V Gorinevskaia[1] says that as a protection against air attacks regimental aid posts in Russia consisted for the most part of tents buried beneath the earth and covered in grass. In these tents urgent operations which included laparotomies and craniotomies were performed within three hours of the injury. The tents were electrically lighted. Flies and mosquitoes were the main difficulty. The chief surgical work consisted of primary wound excision. After treatment the wounded were evacuated in trucks and planes but those who could not be moved remained for further anti shock treatment.

So-called reinforcement groups were found extremely valuable. They consisted of an experienced surgeon, a junior assistant, two nurses (one surgical and one anæsthetic) and two orderlies. They were supplied with an operating table, necessary instruments and a tent. This mobile unit took duty when any particular area became congested. The personnel gave best service when it was divided into units giving opportunity for sleep of not less than six consecutive hours. Twenty four hours of uninterrupted duty proved unsatisfactory.

Aerial ambulances—Ambulance aeroplanes fly wounded patients to hospitals in Germany practically from the battlefield. On board the aeroplanes are emergency therapeutic agents including oxygen. This transportation is not only life-saving but as it lessens the time between the injury and surgical treatment it reduces the duration of convalescence. The wounded are placed in aeroplanes which carry six to twelve beds and eight to twelve seated patients besides the medical officer.[2]

A soldier with prolapse of the small intestine, the result of an abdominal wound received at Warsaw, was transported by aeroplane and reached the operating table in the clinic at the University of Breslau two and a half hours after being wounded. He recovered (W T nnis)[3]

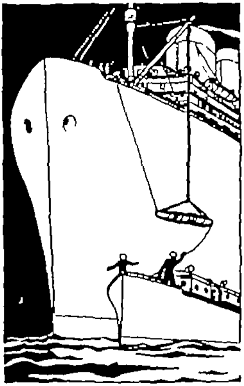


FIG 873

The Stokes stretcher. Hoisting patients aboard ship from a small boat (*After R. H. Laning et al*)

D N W Grant[4] outlines a plan for the rapid evacuation of wounded from the battlefield by air ambulance. Using one squadron of twelve bi motor ambulances and one of eighteen single-motor ambulances between 860 and 2 260 cases can be evacuated in twelve daylight hours for distances varying from 100 to 500 miles. Many patients too ill to be transported over rough and congested roads can be taken by aerial ambulances to well-equipped hospitals. This contributes in no small measure to the morale of the army.

A naval stretcher—The Stokes stretcher (Fig 873) is standard in the U.S Navy and has proved well adapted to requirements (R H Laning *et al*)[5]

Gorinevskaia, V *Khirurgiia* 1940, 2, 12.
Annotation. *United States Naval Med Bul* 1941 39 414.
Tonnis, W., *Military Surgeon*, 1940 87, 32.
Grant, D. N. W *Military Surgeon* 1941, 88, 234
Laning, R. H., *et al* *Surg Cl North Amer* 1941 21 1703.

first edition of this work was out of date ere it was published, and it is particularly unfortunate that repeated requests to be allowed to include a modernized version of this organization have met with no success I have scrutinized the journal of the Royal Army Medical Corps in the hope of finding some details which will help to elucidate the elements of the mechanized field ambulance, in order that we may teach the regimental surgeons of to-day and to-morrow what is expected of them, but again without success The following harbingers have been culled from the Russian and American surgical literature

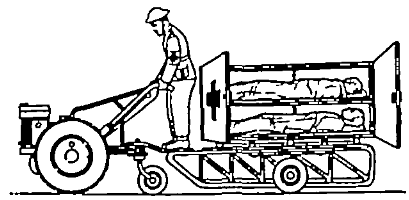


FIG 870

Darnall's mechanized stretcher-bearer

Captain C R Darnall [1] U S Army, stresses the need of a half-ton pick-up truck to enable the medical officer to keep moving, and to transport his regimental aid post to where it is needed He advises replacing the stretcher-bearer by a small caterpillar tractor pulling a sledge or wheeled truck on which is mounted an armoured box which can be opened at either side for the reception of the wounded on a stretcher (Fig 870)

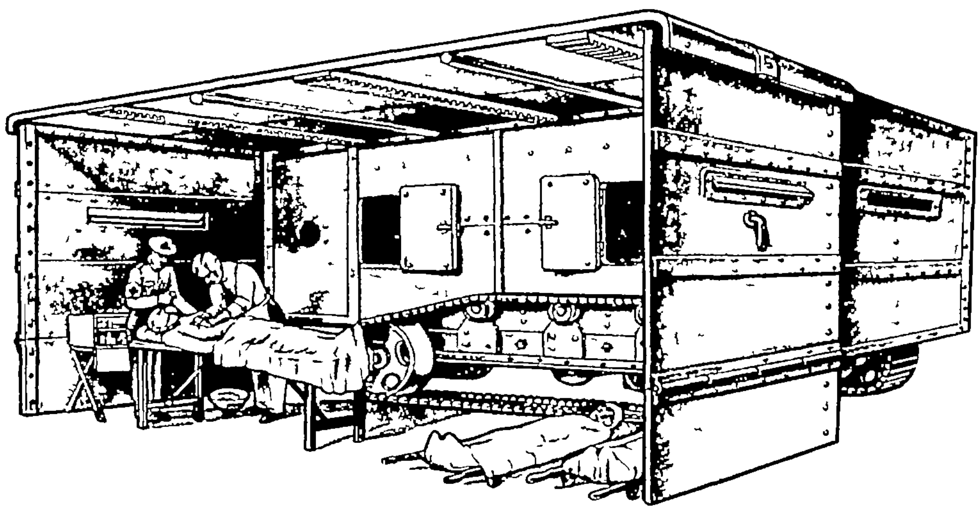


FIG 871

Colonel Hendricks' mechanized first-aid post The sides and roof of the shelter are operated from within the tank by crank mechanism

V Gornevskaia [2] found the conditions on the steppes of Russia favourable for motor transportation of the wounded

Colonel C M Hendricks,[3] U S Army, has designed a tank-like mechanized first-aid station (Fig 871) The armoured steel shelter affords protection when essential surgical operations have to be carried out He has also designed a motor-cycle stretcher carrier for two patients (Fig 872)

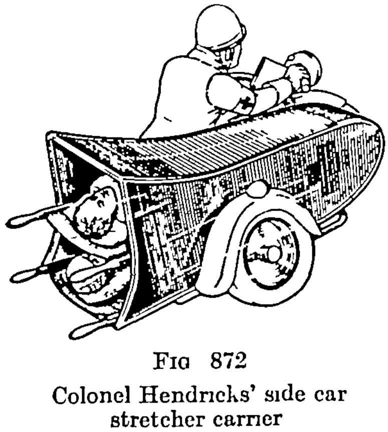


FIG 872

Colonel Hendricks' side car stretcher carrier

[1] Darnall, C R *Military Surgeon*, 1941, 88, 395 [2] Gorinevskaia, V *Khirurgija*, 1940, 2, 12
[3] Hendricks, C M *Military Surgeon*, 1940, 87, 311

T B Magath[1] says that at the Mayo Clinic they have satisfied themselves by bacteriological investigations that of all the antiseptics for the preparation of the skin merthiolate is the most satisfactory Dermatitis occasionally occurs but it is not severe indeed it is considerably less in evidence than when tincture of iodine is employed

J T Nix[2] recommends sterile collodion applied with a spray as a final preparation for the skin Advantages claimed are that it is transparent saves time in clipping towels to the skin edges hermetically seals skin organisms and when the times comes is easily removed Collodion can be sprayed with an ordinary atomizer

Preparation of the surgeon s hands—A S Davletov[3] a Russian surgeon prepares his hands for operation by washing them for five minutes in 0 1 per cent hydrochloric acid with the aid of a piece of sterile cotton wool He then wipes them with 0 15 per cent hydrochloric acid in surgical spirit He claims that this renders the hands more amicrobic than any other method but he does not state how the skin stands repeated acid ablutions

COMPRESSION PHENOMENA

The crush syndrome—R L Benison[4] points out that so often the patient remains comparatively well and cheerful while trapped but dies soon after release He suggests that the phenomenon should be called not the crush syndrome but the release syndrome He further advises that mobile units should be instructed to place a tourniquet on the trapped limb as soon as release has been effected

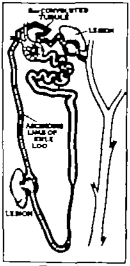


FIG 874
The lesion in anuria due to crush syndrome (Shaw Dunn et al's findings) The ascending loop of Henle and the second convoluted tubules are also affected.

A I L Maitland[5] says that up to April 1941 seventeen cases of the crush syndrome had been described, with twelve deaths. He records a case of a man of forty buried for fifteen hours, pinned by beams which pressed on his right arm and right leg who had passed no urine for thirty nine hours Maitland treated the patient by injections of suprarenal cortical extract complete protein starvation and forced fluids Every form of protein was withheld for eighteen days. Improvement began on the tenth day

D H Patey and J D Robertson advise intermittent pressure to the affected limb on the assumption that crush syndrome is due to loss of substances from the circulation into the damaged limb They apply a pneumatic tourniquet and have designed a suitable one for the lower limb which is inflated by a Pavaex motor

G Blackburn and W W Kay record the case of a man of fifty-eight whose left thigh was entrapped and crushed under fallen masonry On the fourth day the urinary output was as low as 7 oz. One thousand cubic centimetres of 2 per cent. solution of sodium bicarbonate was given per rectum by the drip method About the fourteenth day mild jaundice appeared.

C J Longland and J Murray also record a case of recovery from the crush syndrome. This patient also suffered from mild jaundice, which was noted on the second day In this case the urine did not become alkaline until the seventh day when diuresis began.

J S Dunn M Gillespie and J S F Niven[9] made a very complete histological examination of the kidneys of two patients who succumbed to anuria following crush syndrome They demonstrated that

Magath, T B *Collected Papers, Mayo Cl* 1940, **32**, 120
Nix, J T *New Orleans Med and Surg Jour* 1941, **93** 480
Maitland, A I L *Lancet*, 1941, **2**, 446
Patey, D H and Robertson, J D *Lancet*, 1941 1, 780
Blackburn G and Kay W W *Brit Med Jour* 1941 **2**, 475
Longland, C J and Murray J *Lancet*, 1941 **2**, 15
Davletov, A S *Khirurgiya*, 1940, **9** 66,
Benison, R I *Lancet* 1941 **2**, 776
Dunn J S *et al.* *Lancet*, 1941 **2**, 549

BACTERIOLOGY

C Levaditi[1] made bacteriological studies of war wounds Of 317 cultures, 32 per cent contained three species of organisms, 19 per cent one species, and 19 per cent four species Twenty-three per cent contained five or six species and 7 per cent were sterile The organisms most generally observed were staphylococci (85 per cent), Friedländer's bacillus, Cl welchii, streptococci, colon group, B pyocyaneus L Colebrook[2] estimates that streptococci are responsible for at least 70 per cent of all deaths due to infection of wounds Of forty-nine positive blood cultures, forty-four were hæmolytic streptococci

On antiseptics in general—L E H Whitby[3] has tested in the laboratory many different antiseptics, and has been led to condemn them all as applications to wound surfaces They are mostly " decelerators " of healing

L P Garrod[4] has investigated various antiseptics and their action upon wounds He comes to the conclusion that 0 1 per cent proflavine is the best antiseptic, as it causes the least damage to tissues The emulsion of acriflavine of the B P C is inert because of the presence of the oil The proper vehicle for the application of antiseptics to the tissues is water, and the solution should be isotonic Cyllin, izal and dettol are also energetic antiseptics, and they cause no gross damage to tissues These chemicals may kill or harm leucocytes in the wound, but leucocytes are easily replaced

J E Hamilton[5] investigated the new antiseptic azochloramide on infected wounds He came to the conclusion that it was neither better nor worse than Dakin's solution, and the tendency to skin irritation was not less

" Hospital " infection with special reference to droplet infection—The most important factor in " hospital " infection of wounds is droplet infection from throats and noses From 20 to 40 per cent of persons are nasal carriers of staphylococcus pyogenes The Medical Research Council[6] recommend that impervious masks should be worn by all taking part in dressings or the preparation of materials for dressings J W Hirshfeld and P J Laube[7] have proved that surgical masks reduce direct spray contamination in 89 per cent of tests

J Orr-Ewing *et al*[8] investigated the bacteriology of wounds healing under the closed-plaster treatment The flora appear to be much the same as those which infest wounds treated by other methods As must be obvious, the infrequent dressing minimizes hospital infections However, infection was shown to occur fairly often during reapplication of the plaster

Preparation of the patient's skin—M Novak and H Hall[9] contribute evidence which shows that soap and water alone is inefficient, killing only 53 per cent of organisms on the normal skin The best skin cleanser is 0 07 per cent bichloride and 0 5 per cent tricresol in 10 per cent alcohol and 10 per cent acetone The solution is very inexpensive

W H Prioleau[10] warns us not to be beguiled into a sense of security by painting the skin with a coloured solution

[1] Levaditi, C *Jour Amer Med Ass Foreign Letter*, 1940, **114**, 904
[2] Colebrook, L *Brit Med Jour*, 1940, 1, 448 *Lancet*, 1941, 1, 271
[3] Whitby, L E H *Bull War Med*, 1941, 1, 136 [4] Garrod, L P *Lancet*, 1940, 1, 798, 845
[5] Hamilton, J E *Kentucky Med Jour*, 1939, **37**, 395
[6] Medical Research Council Memorandum, 1941, No 6 London
[7] Hirshfeld J W, and Laube P J *Surgery*, 1941, 1, 720
[8] Orr Ewing J *et al* *Brit Med Jour*, 1941 1, 877 [9] Novak, M and Hall, H *Surgery*, 1939, 5, 560
[10] Prioleau, W H *Southern Med and Surg*, 1941, **103**, 233

Preparations of adrenal cortex—R F Loeb[1] says there is considerable evidence that desoxycorticosterone administered three to six hours before operation will prevent the usual decrease in plasma volume accompanying general anæsthesia in a surgical operation

J Scudder has advocated the use of large quantities of desoxycorticosterone in the treatment of shock.

Several investigators have tried with some success to use cortical extract or desoxycorticosterone in the prevention and treatment of traumatic shock. J C Aub[3] says that most of the studies deal with the prevention of shock rather than its cure and further investigations are needed before this work can be considered established

R. C. Adams[4] states that adrenal cortical extract appears to have value since it tends to restore capillary tone as well as to aid in the redistribution of electrolytes especially of sodium chloride

The analogy between renal insufficiency and traumatic shock was first suggested by W W Swingle *et al*[5] Most observers, *e.g.*, H Selye and C Dosne have found that cortical extract *e.g.*, Percorten (Ciba) and Eucortone (Allen & Hanburys), is better than desoxycorticosterone acetate

[I have convinced myself that cortin preparations are valuable Their present enormous cost limits their wide-spread use —H B.]

Oxygen therapy—J McMichael[7] says that even when 90 per cent of oxygen is present in the lung alveoli it only increases the amount carried by the arterial blood by one tenth To be of any value oxygen must be given in a high concentration This is achieved satisfactorily by the B.L B mask Since the harm resulting from poor circulation ultimately depends upon a poor oxygen supply to the tissues the rationale of oxygen therapy in shock becomes apparent J A Shepherd[8] found that in profound shock oxygen therapy with a B L B mask frequently produced obvious improvement If the patient did not tolerate the mask it usually meant that he did not require oxygen Many patients asked for it to be reapplied if it had been removed

FAT EMBOLISM

Fat embolism consequent upon trauma is generally seen in the fourth decade of life Alcoholic subjects are more prone to the condition. Fat emboli are not true emboli, for they do not occlude a blood vessel permanently There are two varieties —

1 *Pulmonary fat embolism* is again divided into two varieties :—

(*a*) A fulminating type results in the transference of a large mass of liquid fat to the lung It may occur as early as one and a half hours after the injury It causes severe dyspnœa, cyanosis, pulmonary œdema, and usually death

(*b*) The slow form occurs hours or days later The sputum may be blood-stained and contain fat.

2 *Cerebral fat embolism*—Fat is distributed to all organs, but mostly to the brain because of its greater circulation. Like the pulmonary form, there is an early and a late type. Pyrexia or hyperpyrexia is usual. There is deepening coma with signs of cortical irritation (M. Spring)[9]

W F Bowers[10] remarks that fat embolism is often found if especially looked for in necropsies upon traumatic cases. It requires about 200 grammes of fat liberated into the blood stream to produce a fatal result The source of the fat is usually from tissues around the site of injury Fat embolism is frequently confused with shock. The pulmonary form is usually diagnosed as pneumonia, while the cerebro-cardiac forms are confused with shock

R A. Rowlands and C P G Wakeley[11] find that the patients are usually pyrexial. The temperature on an average is about 103 Tachycardia is always present and the mucous membranes often show petechial hæmorrhage The administration of oxygen is helpful. Sodium desoxycholate intravenously in doses of 10 c.c. of a 20 per cent. solution given very slowly in a drip infusion every two hours, has been advocated.

Loeb R. F *Jour Amer Med. Ass.*, 1941, 116, 463.
Scudder J "Shock Blood Studies as a Guide to Therapy" Philadelphia, 1940
Aub J C *New Eng Jour Med.*, 1941, 224, 8?7
Adams, R. C *Military Surgeon*, 1941, 89, 34
Swingle, W W., *et al. Science* 1933 77, 58.
Selye, H., and Dosne, C. *Lancet*, 1940, 2, 70.
McMichael, J *Practitioner*, 1941, 147 526.
Shepherd, J A *Lancet*, 1941 2, 783
Spring, M. *Surg Clin. North Amer.*, 1941 21 543.
10 Bowers, W. F *Military Surgeon* 1941 89, 41.
11 Rowlands, R. A., and Wakeley C P G *Lancet* 1941, 1 50..

the kidney lesion is limited to the ascending limbs of Henle's loop and the second convoluted tubules (Fig 874) They favour a toxic cause, and suggest that uric acid and phosphoric acid may well be the toxic agents, seeing that both these molecules have their origin in muscular tissue in the form of inosinic acid Such a hypothesis is substantiated from animal experiments

(The necessity for alkalinization of the urine is urgent See the best method of effecting this on p 956)

Caisson disease—The term "bends" is strictly applicable to the pains in the extremities, usually in the areas of joints Together with asphyxia and paralysis it constitutes one of the major manifestations of decompression gas embolism Prolonged recompression at six atmospheres, combined with oxygen therapy, usually brings about complete recovery A R Behnke [1] discusses the practical application of helium and argon as a diluting gas for oxygen in relation to deep-sea diving and submarine rescue.

SHOCK

Recording his experience with air-raid casualties, J A Shepherd [2] advises removing all the patient's clothing as soon as he reaches the resuscitation ward Failure to observe this rule results in injuries being overlooked Furthermore, damp clothing is not penetrated sufficiently even by the heat from a shock cage The degree of shock encountered in air-raid casualties far exceeds that seen in casualties of civil life Besides heat, elevation of the foot of the bed on an 18-in block and intravenous therapy with blood plasma or reconstituted serum in large doses is necessary It should be possible to gravitate 2 pints of plasma in twenty minutes, and further quantities up to 6 pints at a rather slower rate as the patient's condition improves

An important piece of work was done by I D Miller [3] showing conclusively the effect of movement on a shocked patient A number of graphs are included which show how the blood pressure falls when the patient is moved

R T Grant and E B Reeve [4] find that normal blood pressure and pulse-rate, and even a good facial colour, are compatible with severe shock and also with a large loss of blood In assessing the gravity of a case, emphasis should be placed on the severity of the injury and loss of blood rather than the blood pressure

The Trendelenburg position is of considerable value in the treatment of shock (W F Bowers) [5]

A K Boyle [6] believes that low spinal anæsthesia is very valuable in the treatment of shock associated with wounds of the lower extremity A *low* spinal anæsthesia is not associated with a fall of blood pressure, and the interruption of pain stimuli is effected by the lumbo-sacral block

A V Vishnevskiy [7] recommends a circular block of local anæsthesia of an injured extremity as a prophylaxis to shock

[1] Behnke, A R *War Medicine*, 1941, 1, 108 [2] Shepherd, J A *Lancet*, 1941, 2, 785
[3] Miller, I D *Australian and New Zealand Jour Surg*, 1936 37, 6, 296
[4] Grant, R T and Reeve E B *Brit Med Jour*, 1941, 2, 329
[5] Bowers, W F *Military Surgeon*, 1941, 89, 41 [6] Boyle, A K *Jour R A M C*, 1941, 76, 330
[7] Vishnevskiy, A V Quoted in *Jour Amer Med Ass*, 1941, 117, 971

Especially when the patient is on the operating table the external jugular vein is often the most suitable for the urgent administration of fluids intravenously. The fixation of the skin and the jugular vein by a towel clip facilitates venipuncture (Fig 880) (F B Tuohy and J S Lundy)[1]

Fig 881
Hand roller for expediting intravenous administration of fluids.

In order to expedite intravenous administration of blood or other fluids in some American clinics the ingenious hand roller depicted in Figs 881 and 882 is in use (R C Adams)[2] [The apparatus appears most practical and it would be an advantage if some progressive surgical firm in this country could make this simple appliance —H B]

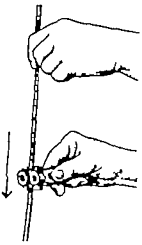
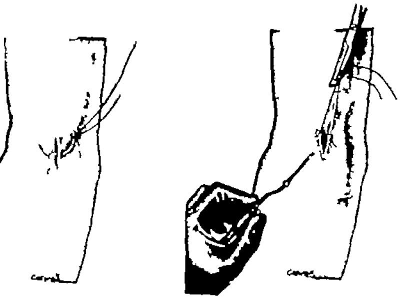


Fig 882
The hand roller in use

CANNULIZATION FOR INFUSION AND TRANSFUSION

E Frankel[3] describes a simple method of tying a cannula into the vein A short oblique incision is made over the vein which is cleared from surrounding areolar tissue by the beak of a hæmostat in the usual way A curved cutting needle threaded with a strand of silkworm gut is passed through one skin edge beneath the vein and through the other skin edge (Fig 883) The ends of the stitch are caught in a hæmostat and traction is exerted this obstructs the vein and makes it conspicuous (Fig 884)



Figs 883 and 884
Frankel's rapid method of cannulising a vein

The vein is then incised the cannula inserted and the suture when tied anchors the cannula in position and closes the skin incision After the conclusion of the transfusion or infusion the suture is cut the cannula

[1] Tuohy F B, and Lundy, J S *Collected Papers Mayo Clin*, 1940 32, 51
[2] Adams, R. C *Military Surgeon* 1941 89 34.
[3] Frankel, E. *Brit Med. Jour* 1941 2, 430.

VENIPUNCTURE

In order to perform venipuncture successfully the veins must be reasonably distended American surgeons favour the application of hot moist Turkish towelling as a preliminary measure E B Tuohy and J S Lundy [1] stress that in order to be efficient these must be applied not purely locally but as indicated in FIG 875

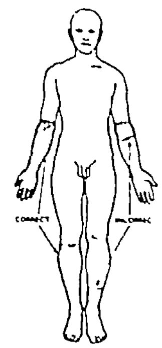


FIG 875
Correct and incorrect applications of heat in order to distend the veins prior to venipuncture

Tuohy and Lundy show a method of ensuring that a needle is within the vein when fluids are given by the intravenous route Fig 876 illustrates the technique better than words

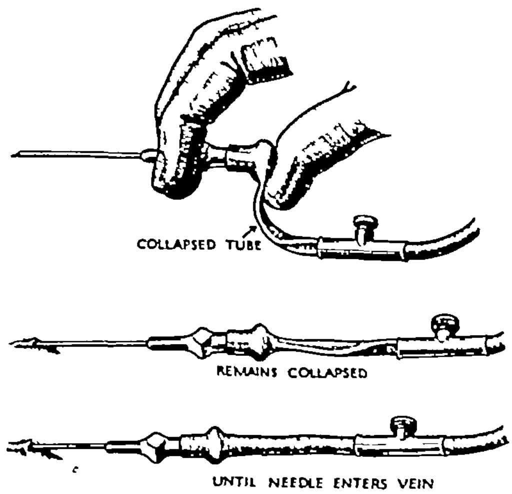


FIG 876
Method of introducing a hollow needle connected with an intravenous saline apparatus according to Tuohy and Lundy

W N Taylor [2] makes an effective vein seeker from the following —

FIG 877
Taylor's improvised vein-seeker

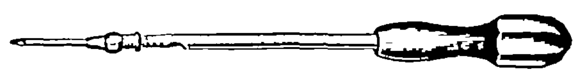


FIG 878
Rudder's mechanical aid for venipuncture
(G-U Manufacturing Co)

(1) The barrel of a 1 c c syringe, preferably of glass (2) A short piece of soft rubber tubing of suitable size to fit over the barrel (3) A small serological test-tube about the same size as the barrel (Fig 877)

F F Rudder [3] has devised a handle which fits a hollow needle for venipuncture With this handle the vein can be entered far more easily, and in view of the widespread difficulty of entering a vein regularly this instrument may prove a distinct asset (Fig 878)

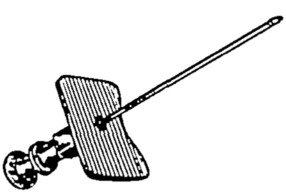


FIG 879
Lewisohn's needle for the administration of intravenous fluids

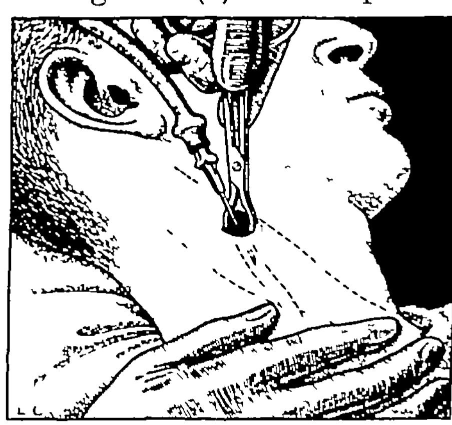


FIG 880
Venipuncture of the external jugular vein The towel clip technique of Tuohy and Lundy

In the U S A Lewisohn's needles (Fig 879) are very popular for administering intravenous fluids via venipuncture They are made in two sizes (E B Tuohy and J S Lundy) [1]

[1] Tuohy, E B and Lundy, J S *Collected Papers Mayo Clin*, 1940 32, 51
[2] Taylor, W N *Brit Med Jour*, 1941, 2, 730
[3] Rudder, F F *Ann Surg*, 1941, 113, 476

S C Dyke[1] says that there is little evidence that advantage lies either with plasma or serum Both serum (Fig 887) and plasma are now being dried on a large scale After reconstitution to their original bulk with sterile pyrogen free distilled water they may be used in exactly the same way and give the same results as before desiccation

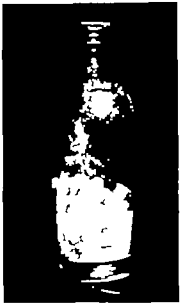


Fig 887

Dried serum (50 gm) It is reconstituted by filling the bottle up to the mark with pyrogen-free distilled water (*F rquharson*)

STORAGE—H Scarborough and J C Thompson[2] show that neither the hæmoglobin content nor the oxygen capacity of the blood is impaired to any important extent by storage at 2 to 5 C. for period up to thirty days On the other hand A Crosbie and H Scarborough state that 74 per cent of the total leucocytes are destroyed by the tenth day of storage

O F Denstedt *et al*[4] affirm that there is general agreement that the presence of glucose in preservative solution greatly improves the stability of the erythrocytes in stored blood

Reactions after transfusions and plasma infusions and their prevention—H F Brewer *et al*[5] show that the number of reactions occurring after transfusions with stored blood is nearly double that of fresh blood When stored blood is used a febrile reaction is to be expected in about 20 per cent of transfusions and an obvious rigor in about 5 per cent (E C O Jewesbury)[6] C P Stewart[7] found a total reaction incidence of 12 3 per cent in transfusions of stored blood not more than fourteen days old He regards fourteen days as the safe limit of storage In the Home Counties the limit usually set is twenty-one days

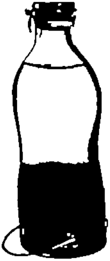


Fig 888

Bottle of preserved blood, showing separation into corpuscular and plasma layers, with narrow intermediate zone of partial hæmolysis. (*F rquharson*)

Unduly hæmolyzed blood should not be used F L Farquharson[8] warns us that a zone of hæmolytic discoloration (Fig 888) extending more than half way up the plasma layer is incompatible with safe administration Turbidity of the plasma suggests the presence of bacterial infection and demands that the blood be discarded

It is customary to pool plasma and serum before storage and most of that issued for use has little or no iso-agglutinin action In giving large infusions of plasma or serum it is advisable to make sure that iso-agglutinins capable of acting upon the red cells of the proposed recipient are absent from the infusion fluid or if present only at a very low titre (B L Della Vida and S C Dyke)[9]

Dyke S C Personal communication
Scarborough, H and Thompson, J C *Ed Med Jour* 1940, 47 567
Crosbie, A., and Scarborough, H. *Edin Med Jour* 1940 47 63.
Denstedt, O F *et al* *Canad Med Ass Jour* 1941 44, 448
Brewer H F *et al* *Brit. Med. Jour* 1940 2, 48.
Jewesbury E. C O *Brit. Med Jour* 1941 1, 661.
Stewart, C P *Edin Med Jour* 1940 47, 441
Farquharson, E L Illustrations of Surgical Treatment 2nd ed. Edinburgh, 1942.
Della Vida, B. L., and Dyke S C. *Lancet* 1941 1 564

withdrawn, and a new skin suture inserted to close the wound Sulphanilamide powder is introduced into the wound before tying the suture

BONE-MARROW INFUSIONS

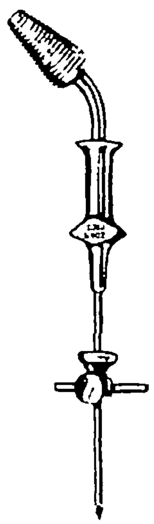


Fig 885 Modified Witts' sternal puncture needle for bone marrow infusion with adapter

I have employed bone-marrow infusions in a small series of cases and have been well pleased with the results Witts' sternal puncture needle was used in a number of instances, and it proved effective At my suggestion Messrs Down Bros have modified the collar of the needle The wings, which are shown in Fig 885, prevent lateral movement of the needle once it is within the bone marrow Down Bros have also made an adapter, bent at a suitable angle, for connecting the needle with the rubber tubing (Fig 885)

For the reception of saline, saline and glucose, and plasma, the bone marrow is excellent, for blood it is slow and sometimes unsatisfactory

INFUSIONS AND TRANSFUSIONS

Continuous rectal saline—The value of the rectal route for administration of saline should not be forgotten Its advantages are obvious, especially in extenuating circumstances The great disadvantage of the rectal route is that absorption is not regularly satisfactory, too often patients who need it most expel the saline To some extent this can be minimized by following the principles laid down by Murphy The height of the reservoir should not be more than one foot above the rectum (Fig 886), the delivery tube should be of comparatively wide calibre, and his glass bulb with many perforations should be employed This glass bulb is not readily obtainable, at any rate in this country A de Pezzer catheter answers the purpose well It is to be noted especially that the tubing of Murphy's apparatus is not intercepted by any form of valve or dripper, consequently flatus can be expelled through the wide rubber tube into the reservoir [1]

Intravenous dextrose—Solutions of dextrose are particularly prone to cause venous thrombosis To a large extent this can be obviated by allowing a little normal saline solution to gravitate into the vein at the conclusion of the administration before removing the needle or cannula (J H Tillisch) [2]

Blood, plasma and serum—H L Marriott and A Kekwick [3] have pointed out that blood or plasma transfusion in cases of severe shock should be rapid—at the rate of 1 pint per fifteen minutes or even faster The amount transfused depends on the severity of shock Patients showing significant reduction of blood volume will require $1\frac{1}{2}$ to 4 pints of blood or plasma

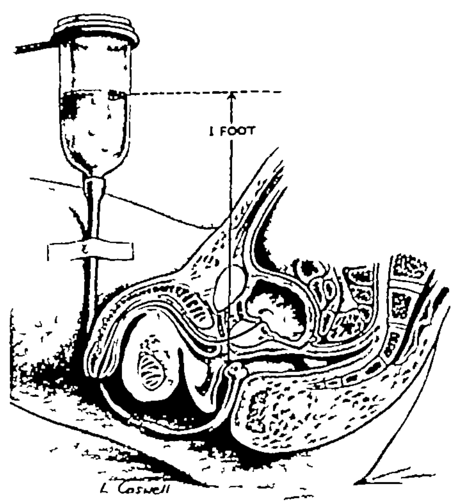


Fig 886
The principles of proctoclysis as laid down by Murphy

[1] Bailey, H Emergency Surgery, 5th ed Bristol 1942
[2] Tillisch, J H *Collected Papers Mayo Clinic*, 1940, 32, 42
[3] Marriott, H L, and Kekwick, A *Brit Med Jour*, 1940, 2, 467

S C Dyke[1] says that there is little evidence that advantage lies either with plasma or serum. Both serum (Fig 887) and plasma are now being dried on a large scale After reconstitution to their original bulk with sterile pyrogen free distilled water they may be used in exactly the same way and give the same results as before desiccation

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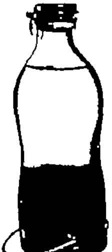

FIG 888

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Unduly hæmolyzed blood should not be used E L Farquharson[8] warns us that a zone of hæmolytic discoloration (Fig 888) extending more than half way up the plasma layer is incompatible with safe administration Turbidity of the plasma suggests the presence of bacterial infection and demands that the blood be discarded

It is customary to pool plasma and serum before storage and most of that issued for use has little or no iso-agglutinin action In giving large infusions of plasma or serum it is advisable to make sure that iso-agglutinins capable of acting upon the red cells of the proposed recipient are absent from the infusion fluid or if present only at a very low titre (B L Della Vida and S C Dyke)[9]

Dyke S C Personal communication.
Scarborough, H., and Thompson, J C *Edin Med Jour.*, 1940, 47 56
Crosbie, A and Scarborough, H. *Edin Med Jour* 1940 47 53
Denstedt, O F *et al.* *Canad. Med Ass Jour* 1941 44, 448.
Brewer H F *et al.* *Brit. Med. Jour* 1940 2, 48.
Jewesbury E. C O *Brit. Med Jour.*, 1941 1, 643
Stewart, C P *Edin Med Jour* 1940 47 441.
Farquharson, E. L. "Illustrations of Surgical Treatment 2nd ed. Edinburgh, 1942.
Della Vida B L and Dyke S C *Lancet* 1941 1 364

G E O Williams[1] gives practical hints regarding the sterilization of bottles Since this received attention at the Merseyside War Blood Bank there has been no trouble by contamination of blood or plasma Sulphanilamide in concentrations of 1 1,000 to 1 5,000 is effective as a preservative in blood stored in the refrigerator at 2° C (R F Hunwicke)[2]

H F Brewer *et al*[3] point out the importance of purity in the anti coagulant solution and its sterile preparation, and the need for scrupulous cleanliness in all the apparatus The rubber tubing should be cleansed with a stiff wire carrying a swab Strict surgical asepsis should be observed while collecting the blood, and storage carried out at 2° to 5° C

J Vaughan and H Brown[4] found that no severe reactions followed plasma infusions F Mayner[5] publishes a case of death following plasma infusion Necropsy showed subacute glomerular nephritis and multiple emboli of fibrin in the terminal pulmonary vessels and capillaries In this country plasma is carefully filtered before issue, and it is passed through a filter during administration, thus fibrin emboli are most unlikely to occur

After experimenting with various drugs, M Bick and E B Drevermann[6] have come to the conclusion that for rapid alkalinization of the urine, such as is required after incompatible blood transfusion, there is no better method than injecting intravenously 10 c c each of isotonic sodium lactate solution and a saturated solution of sodium bicarbonate To be of any use these drugs should be at hand for every transfusion There is no difficulty in this,[7] for Crookes Laboratories put up these drugs ready for use in ampoules

Plasma substitutes—U Maes and H A Davis[8] have used *ascitic fluid* from cases of cardiac failure and portal cirrhosis as a substitute for plasma Ascitic fluid is sterile and can be stored for as long as five months at 0 5° C Fifty cubic centimetres of a 5 per cent solution of sodium citrate is added to each litre of ascitic fluid in order to prevent fibrin clots forming It is necessary to cross match the ascitic fluid with the blood of the recipient The fluid is warmed and filtered through fifteen layers of gauze before administration

Isinglass is suggested as a substitute for plasma It is obtained from the swimming bladders of fish In experiments the fluid was found to be satisfactory with the exception of occasional anaphylactic reactions, attributed to fish protein contamination of the isinglass It is expected that the isolation of a purer product will obviate this disadvantage (N B Taylor and E T Waters)[9]

LOCALIZATION OF METALLIC FOREIGN BODIES

C W Cutler[10] details an effective method of localizing an opaque foreign body in the hand Two fine wires, such as tonsil snare wire, are fixed by strapping in such a way as to form a cross at the site of entrance (Fig 889, A) or at the spot of greatest tenderness Radiographs are taken in two planes (Fig 889, B), at right angles to each other (Fig 889, C)

J S Hall[11] has overcome the difficulty of finding small metallic fragments in the tissues by taking a wireless set into the operating theatre and connecting an insulated probe to the aerial terminal

[1] Williams, G E O *Brit Med Jour*, 1940, 2, 830
[2] Hunwicke, R F *Brit Med Jour*, 1940, 2, 380
[3] Brewer, H F, *et al* *Brit Med Jour*, 1940, 2, 48
[4] Vaughan, J, and Brown, H *Proc Roy Soc Med*, 1941, 34, 203
[5] Mayner, F *Jour Amer Med Ass*, 1941, 116, 2015
[6] Bick, M, and Drevermann, E B *Med Jour Australia*, 1941, 8, 223
[7] Bailey H Emergency Surgery, 5th ed Bristol, 1942
[8] Maes, U and Davis, H A *Arch Surg* 1941, 42, 453
[9] Taylor N B, and Waters, E T *Canad Med Ass Jour*, 1941, 44, 547
[10] Cutler, C W *Surg Clin North Amer*, 1941, 21, 485 [11] Hall, J S *Brit Med Jour*, 1940, 2, 611

Touching a piece of metal produces a loud, characteristic "click" or scratching noise in the loud speaker which is easily distinguishable from the noise produced by touching non metallic objects. The valve-operated wireless set is switched on to full volume The programme is tuned out leaving the set still in a sensitive condition, so that a finger touching the aerial terminal gives an audible

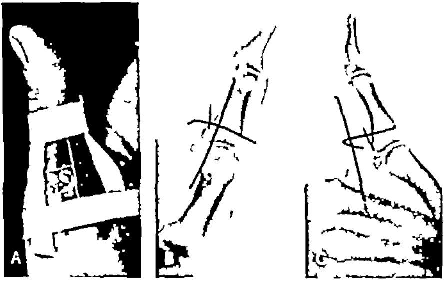

FIG 889

Localization of a foreign body in the thumb
(*C W Cutler's method Reproduced by kind permission of W B. Saunders & Co*)

sound in the speaker A few feet of wire ending in an insulated probe is connected to the aerial terminal. A diathermy bladder electrode attached to a piece of single flex makes an efficient seeker or a few inches of stout silver wire covered with valve tubing almost to the end can be substituted In either case the wire or the probe must be sterilized before use

LOCAL ANÆSTHESIA IN WAR SURGERY

J E H Roberts [1] warns us that blast injuries of the lungs are one of the most important contraindications to an inhalation anæsthetic As these lung injuries are very common in modern warfare and as they are not by any means always obvious there seems to be a definite indication for the extended use of local anæsthesia The literature seems to indicate that local anæsthesia is used widely by the Russian military surgeons and that it has been found eminently satisfactory A very dilute solution i e $\frac{1}{4}$ per cent novocain has been employed

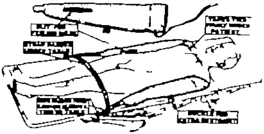

FIG 890

Sister Pauline's apparatus for restraining movement during operations under local anæsthesia.

H Dodd [2] recommends the addition of indigo-carmine to local anæsthetic solutions in order to indicate exactly how far the tissues have been infiltrated

Sister Pauline [3] has evolved a useful piece of apparatus for restraining patients during operations under local anæsthesia In no sense does it make them feel imprisoned There is a sleeve for each arm and a strong tape joins the two sleeves behind the patient's back (Fig 890)

[1] Roberts, J E. H. *Proc. Roy Soc. Med* 1940 34, 91 [2] Dodd, H *Brit Med Jour*, 1940 2, 345.
[3] Pauline, Sister. Quoted by Bailey and Love Surgery for Nurses 5th ed. London, 1942.

PRIMARY WOUND EXCISION—TECHNIQUE

R A Griswold[1] extols the method of carrying out excision of a wound under a constant stream of sterile saline Provision should be made to prevent the fluid running on to the operating table and soaking the patient A most effective gadget has been described by Henry Marble (Fig 891) The gauze sleeve which slips over the pan is made by stitching the end of the fabric together so as to form a tube This supports the limb like a hammock It should be noted that this sleeve is not made of surgical gauze, which would be too frail It is made of what the Americans call " domestic hard-ware cloth " and what we call " dish-cloth " The constant stream of saline floats up torn tissues which have a poor blood supply They are thus easily recognized and excised Hæmostasis is obtained principally by pressure A minimum of the finest ligatures should be employed The dissection can be carried out much more accurately with a scalpel than with scissors

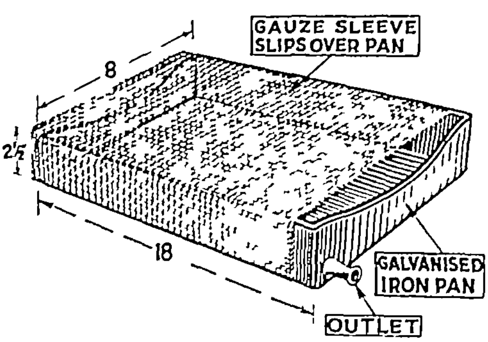

Fig 891
Marble's collector for use in irrigating wounds

R H Kennedy[2] gives instructions for the technique of excising a wound The wound is first packed with gauze in such a way that the skin can be cleansed up to the margin without fear of further contamination A large area of skin is then shaved, scrubbed with soap and water for at least five minutes by the clock, ether being used to remove grease as necessary After drying, the skin is painted with suitable antiseptics The gloves are changed If local anæsthetic is to be used, it is injected The pack is then removed The wound surface is then scrubbed gently with soap and water, and free irrigation with normal saline without pressure is played over the wound This should be supplied through a small jet Fresh towels are then applied about the wound In order to preserve the colour of healthy tissue, it is preferable to work without a tourniquet One-eighth of an inch of skin margin is excised An attempt is made to keep the excised area in one piece Wherever blood-staining is encountered, if it is feasible, this part is included in the portion excised Gentle irrigation is kept up throughout the excision, and portions of tissue removed are sent for bacteriological examination

S J Hoffman[3] records an experience of 700 air-raid casualties when the skin around the wound was scrubbed with soap and water and painted with iodine The wound itself was scrubbed with a brush and dilute lysol—2 drachms to the pint This stains dead and dying tissue a dirty grey and makes its recognition easy Wounds were made into open gutters as far as possible

[1] Griswold, R A *Southern Surgeon*, 1941, 10, 630
[2] Kennedy, R H *Connecticut State Med Jour*, 1942, 6, 9
[3] Hoffman, S J *Brit Med Jour*, 1941, 1, 785

INFECTED WOUNDS

A. Callam and A Duff [1] discuss what they call wound phagadena This condition has been referred to in the recent literature as spreading sub cutaneous gangrene (Fig 892) Phagadena to-day is usually associated with the sloughing condition of the male external genitalia caused by anaerobic organisms but in the past phagadena had a much wider applica tion and was one of the varieties of hospital gangrene Fortunately spreading subcutaneous gangrene is rare Callam and Duff describe two cases The first followed appendicectomy for acute appendicitis and in spite of every form of local and general treatment the gangrene spread over the entire abdominal wall and the patient died The second patient was a man of fifty four and the sloughing process followed an operation for empyema Sulphonamide therapy produced no improvement Local treatment with zinc peroxide gave some promise but the condition soon relapsed and the patient became very low and symptoms of confusional in sanity appeared As a last resort the whole sloughing area was excised Improvement was soon established and the patient recovered

FIG 892

Spreading subcutaneous gangrene (syn. wound phagadena) following an operation for empyema.

Urea in the treatment of infected wounds is praised by F V Stonham [2] He refers to the work of Kirk (1915) who employed urea in infected wounds commencing in 1911 and continuing to practise it with enthusiasm through out his surgical career Kirk opened the abscess dried the cavity powdered it with urea and closed the skin with continuous sutures and very often obtained a first intention healing Urea is cheap and easily obtained and Stonham s observation tends to support Kirk s enthusiasm for this substance

Pectin in the treatment of infected wounds—C A Tompkins *et al* [3] speak highly of the treatment of wounds in general and infected wounds in particular with pectin. To prevent the growth of fungi in the pectin aqueous merthiolate was added 1 200 000 Sterile gauze dressings are saturated with the pectin solution and are changed as often as necessary to keep them moist By using vaseline gauze over the dressing evaporation is reduced to a minimum and the dressings only need to be changed two or three times a week

Prevention of malodour associated with closed plaster—S L Higgs [4] has found that deodorizing bags are successful in preventing smell although

[1] Callam, A., and Duff, A. *Brit Med Jour.*, 1941, **2**, 601.
[2] Stonham, F V *Jour R.A.M C.*, 1941, **77** 240
[3] Tompkins, C A *et al.* *Surg Gynec and Obst.*, 1941 **72**, 222
[4] Higgs, S. L. *Proc Roy Soc Med* 1941, **34**, 215.

they have the disadvantage that, in the case of the arm, the hand can neither be examined nor used freely

After a large experience of Winnett-Orr treatment of osteomyelitis, A D Wallis and M J Dilworth [1] have found that a 12 per cent solution of lactose, dissolved in distilled water and autoclaved, prevents the malodour of the cases treated by the closed-plaster method, at any rate in cases of osteomyelitis They pack the wound with gauze soaked in this solution instead of vaseline gauze Since B pyocyaneus has little or no ability to utilize sugar, this method does not affect its odour, which is not nearly so offensive as that produced by other organisms

TETANUS

H H Brown [2] suggests that it would be a wise course to perform simultaneous immunization against tetanus and typhoid for all those on active service I H Maclean and L B Holt [3] confirm that the administration of combined tetanus toxoid and T A B *is a sound proposition*, and the reaction following the combination is no greater than when one is administered alone H M Perry [4] stated that 80 per cent of the B E F were protected by active immunization by tetanus toxoid, and that it was intended that every casualty, irrespective of prior immunization, should receive 3,000 international units of tetanus antitoxin That the incidence of tetanus in the present war had been 0 05 per thousand, compared with 8 per thousand in the 1914-18 war, fully justifies the wisdom of the measure

W M Firor [5] gives convincing experimental proof of the efficacy of intrathecal administration of tetanus antitoxin Dogs were given approximately double the lethal dose of tetanus toxin intravenously Fifty hours later, when signs of tetanus had become manifest, they were given treatment When the intracisternal route was used for the administration of antitoxin, only three out of thirty-six dogs died, whereas the same dose given intravenously saved only six out of twenty-five The lumbar intrathecal route was rather less effective than the intracisternal, but still much superior to the intravenous

In order to give adequate rest in cases of tetanus, R Spaeth [6] recommends avertin per rectum with amylene hydrates

H N Davis [7] found that an injection of pentothal sodium was very useful in controlling spasms of tetanus during a patient's journey in an ambulance Ten cubic centimetres of a 1 15 solution were employed A generalized spasm was induced by the prick of the needle, but the arm was easily controlled by an assistant

J Bryant and H D Fairman [8] treated twenty-two patients with tetanus by M & B 693, and by continuous or intermittent narcosis with sodium evipan, with only five deaths The patients were natives of the Dinka district of the Equatorial and Upper Nile provinces, and antitetanic serum was not available Evipan was given in doses to produce continuous drowsiness, and the dose increased until all convulsions had been controlled The patients were fed through a tube The M & B 693 was injected intramuscularly in quantities of one tablet to 5 to 10 c c of saline Three to five injections were given

GAS GANGRENE

Substantiation that gas gangrene occurs from anaerobic organisms harboured by clothing rather than the soil is afforded by A Hindhaugh's [9] communication Six cases of gas gangrene occurred in wounded sailors on board ship

U Maes [10] calls our attention to the susceptibility of the heart muscle

[1] Wallis, A D, and Dilworth, M J *Brit Med Jour*, 1941, 1, 750
[2] Brown H H *Lancet* 1939, 2, 1047
[3] Maclean I H, and Holt L B *Lancet* 1940, 2, 581
[4] Perry, H M *Brit Med Jour* 1940, 2, 364
[5] Firor, W M *Arch Surg*, 1940, 41, 209
[6] Spaeth, R *Amer Jour Dis Child*, 1940, 60, 130
[7] Davis, H N *Brit Med Jour*, 1941, 1, 14
[8] Bryant, J, and Fairman, H D *Lancet*, 1940, 2, 263
[9] Hindhaugh, A *Jour Roy Naval Med Serv* 1941, 27, 158
[10] Maes, U *Arch Surg*, 1940, 41, 393

to the toxin of vibrion septique which makes it necessary for the cardiac state to be watched for a long time after the patient has recovered from his infection

X RAY THERAPY—The inclusion in this work of a chapter devoted to the treatment of gas gangrene by deep X-ray therapy has come in for a considerable amount of adverse criticism My mind is entirely open on the subject because I have never seen a case treated by this method The number of cases which have been so treated in this country is ridiculously small, and it seems to me to be fundamentally unscientific to pass an opinion on something we have not investigated. In this connection I have found that those who are loudest in their condemnation of this form of therapy have had no more experience in its use than myself. We cannot ignore the recorded observations of surgeons of the highest attainments. Maes[1] says: "When the work of Kelly and others on X ray treatment is considered, one must accept the fact that X ray treatment lowers the mortality The report of a death rate of 11 3 per cent by Kelly certainly represents a decided improvement, and gives support to the contention that amputation and extensive incisions should be abandoned. It is believed that X-ray therapy causes hydrogen peroxide to be generated in the tissues, and this is the important factor in combating the infection" H J Nightingale[2] a surgeon who had unique experience in the surgical treatment of gas gangrene during the 1914 18 war considers deep X ray therapy in gas gangrene is certainly worthy of trial. It proved very successful in one case observed by him following a motor injury At the Prince Henry Hospital, Sydney H Ham[3] writes that the surgical staff have been profoundly impressed by the results of deep X ray therapy in gas gangrene All patients recovered from the infection, and in no case has amputation been necessary A. J Williams and H V Hartzell[4] analysed thirty four cases of gas gangrene treated in five years at San Francisco Hospital by X ray therapy where it has been used since 1928 The surgeons of this hospital are convinced that it is specific. These authors believe that regardless of what other forms of therapy are employed, all cases should have the benefit of this treatment W H Godby[5] points out that mobile machines are now procurable to treat any type of lesion quickly and thoroughly Of three patients so treated by Godby all being too ill for any further intervention, two lived. From these reports, and a further study of the literature it would appear that many American surgeons are quite convinced that deep X ray therapy is of remarkable value that the surgeons in the British dominions are inclining to this view but that the majority of those in the mother country have not investigated this form of therapy

SURGICAL MATERIALS AND DRESSINGS

Ligatures and sutures—Almost every surgeon I meet complains about the catgut now available. The grading is inaccurate the tensile strength doubtful many of the brands available are most difficult to handle some being very slippery but the bitterest complaints are from reactions, if not actual sepsis, in clean wounds. According to E. L. Howes[6] catgut encourages infection by acting as a culture medium. It is not well tolerated by muscle or fat, where the poor blood supply is probably responsible for low-grade inflammatory reaction with considerable induration.

Thread—D L Davies[7] recalls that the late Mr A Barker Surgeon to University College Hospital used linen thread for all his surgical work i e for intestinal sutures ligatures of arteries fascial planes and the skin G H Colt[8] remarks that linen thread can be boiled in water which is alkaline without becoming rotten whereas the slightest trace of alkali rots silk

Cotton—H Platt[9] writes that at the Manchester Royal Infirmary he has been employing Coats No 40 black cotton as a cheap substitute for linen thread It is boiled for five minutes T A Hindmarsh[10] has employed Coats No 24 black cotton especially in goitre operations with entire satisfaction Indeed he says it has a lot to recommend it other than economy There is less serum collection than when catgut is employed and its tensile strength does not diminish with boiling

1 Maes U *Arch Surg*, 1940, 41 393
2 Nightingale H J *Brit Med Jour* 1940, 2, 166.
3 Ham H *Med Jour Australia* 1940 2, 287
4 Williams, A. J and Hartzell, H. V *Western Jour Surg*, 1939 47 561
5 Godby W H *Med Jour Australia*, 1940, 1 85
6 Howes, E L *Surg Gynec and Obst* 1941 72, 310
7 Davies D L *Lancet* 1942, 1 309
8 Colt, G H *Brit Med Jour* 1941 1 281
9 Platt, H *Lancet* 1942, 1 399
10 Hindmarsh, T A *Lancet* 194–, 1 429

K P A Taylor,[1] an American surgeon, says the disadvantages of cotton are that the tensile strength is lower than catgut and the interrupted suture technique, which goes with it, is slow On the other hand, J O Bower *et al* [2] state that unabsorbable suture materials have been growing in popularity in the United States in recent years

P Thorek [3] says that at the Cook County Hospital, Chicago, cotton as a suture and ligature material is becoming very popular It is very inexpensive and easy to sterilize, either in a steam autoclave for ten minutes at 15 lbs pressure or by boiling for twenty minutes It has been found that if the cotton is wrapped around ordinary rubber tubing its tensile strength will not be diminished by boiling it

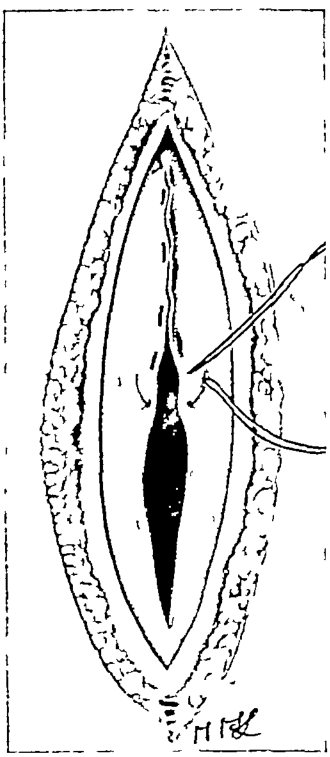

FIG 893

Peritoneum being closed with a continuous No 24 black cotton thread, doubled (*After K P A Taylor*)

Thorek has tried to standardize the gauge, bearing in mind the established fact that the finer the suture material used, the better the result In order to avoid confusion, which will necessarily follow if a number of gauges are employed, he has found it satisfactory to utilize No 24 for all purposes, and to date he has noticed no ill effects from so doing While K P A Taylor advocates the use of cotton as a continuous suture, most observers follow the teaching of Halstead, namely, to use non-absorbable material only as interrupted sutures To obtain the best results with cotton the surgeon's assistant must be instructed to cut as close to the knot as possible In Thorek's experience cotton is just as reliable in contaminated cases, *e g*, perforated appendix, as in clean cases He has intentionally used cotton in grossly contaminated wounds for the sole purpose of determining whether or not a sinus would form Up to the present he has seen no sinus develop

Those who have been brought up to regard unabsorbable sutures as heretical, may gain confidence, as I have done, from an illustration (Fig 893) appearing in a 1941 American journal It seems probable that cotton will be used widely and also that a small proportion of troublesome sinuses will follow —for that has always been the objection to unabsorbable buried sutures Perhaps the local application of sulphonamide powder will reduce the incidence to vanishing point If so a great advance has been made

Vaseline gauze dressings—W H Ogilvie [4] gives details for packing a wound with vaseline gauze The strips are packed into the cavity, particularly into all recesses and intermuscular planes When the wound has been filled vaseline is smeared on to the skin around the wound This is followed by a layer of plain gauze to cover the wound

[1] Taylor, K P A *Southern Surgeon*, 1941, 10, 125
[2] Bower, J O *et al* *Amer Jour Surg*, 1940, 47, 20
[3] Thorek, P *Amer Jour Surg*, 1942, 55, 118
[4] Ogilvie, W H *Practitioner*, 1940, 145, 337

H J McCurrich[1] deplores tight plugging of wounds with vaseline gauze If packing the wound is overdone he says the vaseline gauze acts as a cork and its object is defeated

A. T Forbes[2] questions whether vaseline can be adequately sterilized by the instructions usually given According to the Extra Pharmacopœia these dressings can only be sterilized by heating them to 150 C for one hour

Zipp—S T Hoffman[3] reports favourably on a large series of air raid casualties in which the following modified Zipp was smeared on the wounds after primary excision —

Zinc peroxide Iodoform Sulphanilamide	Equal parts
Paraffin	q s to make a thin paste

W V Connell[4] says that he tried modified Zipp made with zinc peroxide and found it not nearly so satisfactory as the original Zipp for it tended to liberate free iodine

A method of treating granulating areas—A Edmunds[5] has had satisfying results from treating superficial granulating areas often infected as follows Tubes similar to Carrel s tubes are sandwiched in six or more layers of gauze as shown in the diagrams (Figs 894 and 895) The granulating area is covered by a single layer of tulle gras The pad soaked in ½ per cent chloramine is then laid upon the tulle gras and after jaconet and wool the whole is bandaged The pad is kept moist by injecting 1 oz of fresh antiseptic fluid down the tubes every six hours Under this dressing granulating wounds heal readily skin grafts take well and labour is minimized

Figs 894 and 895
Edmund s sandwich dressing for granulating areas

An absorbent for discharging wounds—K Knowles[6] states that for discharging wounds bags filled with fine sawdust have for many years been used in a large mission hospital in Kashmir They are easily prepared and sterilized and are cheap as well as satisfactory

Aids in the management of adhesive dressings—One of the great disadvantages of flexible adhesive plaster is skin irritation produced thereby R F Legge[7] has shown that painting the skin with compound tincture of benzoin helped considerably in preventing erythema pustules vesicles and bleeding

J Gordon[8] says that often nurses complain that if collodion has been used to seal the dressing the stitches are difficult to remove So often they attempt to release the collodion with ether if alcohol is used the dressing can be peeled off easily and the stitches removed without difficulty

Amnioplastin—For many years surgeons have been looking for an ideal wrapping material Cargile membrane has held the field for want of a

McCurrich, H J Personal communication.
Forbes, A T *Lancet* 1941 1 653.
Hoffman, T *Brit Med Jour* 1941 1 85.
Connell, W V *Lancet* 1942 1 30
Edmunds A. *Lancet*, 1941 2, 130.
Knowles, K *Brit. Med Jour.*, 1940 2, 896.
Legge R F *Jour Amer Med Ass* 1941 117 1783.
Gordon, J *Lancet* 1941 1 788

better material Amnioplastin appears to have decided advantages over anything yet produced Lambert Rogers[1] gives the following report "For some time efforts have been directed towards finding some substance which would isolate a damaged structure by preventing it adhering to its surroundings and which, by ultimately becoming absorbed, would leave the structure concerned quite free from its coverings Penfield[2] *et al* experimented on cats by placing various membranous materials between the scarified cerebral cortex and a flap of overlying soft parts They found that of the materials used the best was a prepared form of human amniotic membrane which they called amnioplastin This was absorbed in about three weeks, leaving the cortex free from adhesion to its coverings"

The membrane is preserved in 70 per cent alcohol and boiled for half an hour in distilled water just before using It is not unduly fragile, is easily handled and resembles rather thin oiled silk The site of the lesion, *e g*, part of the cerebral cortex, a suture line, a length of nerve, a damaged tendon or a structure such as the common bile duct, is well covered with the membrane and as far as possible put at rest In the case of a peripheral nerve, this is done by placing the part in a plaster cast until the amnioplastin is absorbed, *i e*, for about three weeks (Chao[3])

Lambert Rogers[4] has used amnioplastin in eight intracranial cases, ten cases of peripheral nerve injury and in one or two other cases, such as that of an adherent scar due to a shell wound in the popliteal space He has not yet had an opportunity of reopening the wound and inspecting the field in a case in which amnioplastin has been used, but it has so far given very satisfactory clinical results In two cases of median causalgia relief of pain was immediate and striking after isolation of the nerve by amnioplastin Restoration of early function has been noted in cases in which it has been used after freeing nerve strangled in scar tissue Results are so encouraging as to suggest its continued and further use

A surgical glue—A preparation of plasma which clots into a firm jelly on the addition of tissue extract is described by J Z Young and P B Medawar[5] They have used it experimentally for joining divided nerves It might prove useful for other surgical procedures

SKIN GRAFTING

B K Rank[6] says that in 72 per cent of cases in which the "take" was not complete, failure was attributable to surface sepsis The infection is usually of low grade, and causes little disturbance to the patient's general condition A Thiersch graft placed on an infected granulation surface will fail Inadequate pressure is another cause of failure, a pressure dressing should be left undisturbed for seven days

In 191 cases Thiersch grafts were applied to surgically created surface wounds, and in 83 per cent of cases the "take" was either complete or good A recently created and sterile raw surface is the ideal base for a Thiersch graft The widespread impression that skin will only take on fatty, fibrous, or granulation tissue is quite erroneous The "take" is always exceedingly good on muscle

N Neuhof[7] reports the successful transplantation of a toe for a missing finger Seventeen years have elapsed since the transplantation

[1] Rogers, L Personal communication
[2] Penfield, W *Brit Med Jour*, 1940, 2, 668
[3] Chao, Y, *et al* *Brit Med Jour*, 1940, 1, 517
[4] Rogers, L *Brit Med Jour*, 1941, 1, 587
[5] Young, J Z, and Medawar, P B *Lancet*, 1940, 2, 126
[6] Rank, B K *Brit Med Jour*, 1940, 1, 846
[7] Neuhof, H *Ann Surg*, 1940, 112, 291

VASCULAR SURGERY

A possible substitute for heparin—Heparin is very expensive and its mode of administration is rather complex A substance which could be applied more readily would be welcome Sweet clover disease has long been known in cattle It occurs when the cattle eat improperly prepared hay and the main symptom is bleeding which may prove fatal It has been shown that Coumarin is the active principle in the hay which causes diminished coagulability of the blood H R Butt *et al* [1] working at the Mayo Clinic have shown experimentally that Coumarin has no ill effects It can be given by mouth and has a prolonged action They think it may replace heparin

R. Leriche and M G Werquin [2] warn us that ligature of a main artery may be followed by massive gangrene or minor degrees of malnutrition of the limb These include partial gangrene ischaemia, claudication and trophic disturbances. Many of these untoward phenomena can be avoided by the following expedients :—

(*a*) By obviating the lowered general blood pressure as soon as possible by suitable blood transfusion.
(*b*) By the substitution of suture for ligature This, however is generally impossible in war wounds.
(*c*) By resecting a segment of the damaged artery as opposed to simple ligation.
(*d*) By performing periarterial sympathectomy above the ligature.
(*e*) By injecting with local anaesthetic the regional sympathetic plexus.

All these methods, to be efficacious, must be done at the time of the original operation because tissues die quickly

THE HEAD

In hair-cutting and shaving of the scalp in head injuries V Gorinevskaia [3] working in the steppes of Russia found that much time was wasted in cases of head injury owing to the hair being matted with blood and soiled with sand Razors and hair-cutting machines were soon blunted He advocates that professional barbers should be attached to the medical corps and the entire personnel be instructed by them in hair-clipping and shaving of the scalp G F Rowbotham [4] gives the following instructions Cut the hair short with scissors comb it then scrub it with a sterile nail brush with soap and water and finally shave it

Ninety two per cent of fatal accidents to motor cyclists are due to head injuries H Cairns [5] considers it should be compulsory for all motor cyclists to wear crash helmets

In acute cerebral compression, when other measures have failed and the patient s condition is desperate H von Briesen and E M Jones [6] recommend drainage of the cisterna magna The dangers of lumbar puncture in this condition are well known If the cisterna magna is drained there is no fear of crowding the brain stem, indeed pressure in this vital neighbourhood is relieved These authors effect drainage by making a small trephine hole low down in the occipital bone to one side of the middle line With a blunt grooved director they perforate the cisterna magna and insert a drainage tube

Butt H R *et al* *Proc Staff Meet. Mayo Clin.*, 1941 16, 388
Leriche R and Werquin, M. G *Lancet*, 1940, 2, 296.
Gorinevskaia, V *Khirurgiya*, 1940, 2, 12.
Rowbotham, G F "Acute Injuries of the Head. Edinburgh, 194..
Cairns H *Brit Med. Jour.*, 1941, 2, 465
Briesen, H von, and Jones, E. M. *Amer Jour Surg* 1940 50 126.

In a case quoted, the patient had awakened from deep unconsciousness in twelve hours. His pulse previously was 150 and Cheyne-Stokes respiration was in evidence. The drain was removed on the second day and the patient made an uneventful recovery. These authors refer to the work of Ody of Switzerland, who in 1932 reported two similar recoveries after drainage of the cisterna magna in moribund cases.

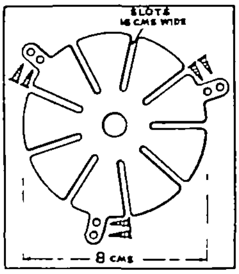

FIG 896
Vitallium skull plate
(*After F W Geib*)

Ody drained the cisterna magna through the middle line by removing a portion of the first and second vertebræ.

F W Geib[1] recommends vitallium plates (Fig 896) for skull defects. Vitallium has not the disadvantages of other metal plates, for it is electrically neutral and does not corrode within the body.

THE FACE AND JAWS

For suturing wounds of the face F P Kintz[2] recommends nylon sutures which have about the same elasticity as horsehair.

J Gordon[3] has found that by using appropriate fine instruments and suture material, hair-line scars can be achieved in wounds of the face. The instruments he recommends are a small needle-holder, a pair of 4½-in Felchenfeld's splinter forceps, and silkworm gut on a curved cutting needle, preferably attached by the eyeless method. Usually the stitch is placed continuously, but the individual loops are left loose until the suturing has been completed. They are then pulled tight, one by one, thus obtaining correct apposition of the skin edges. A gauze and collodion dressing is then applied in the case of adults, but in children it is safer to cover the dressing with flexible adhesive plaster.

Fractures of the mandible—A B MacGregor[4] describes an ingenious appliance for the treatment of fractures of the angle of the mandible in cases where internal splints are contraindicated. The appliance enables direct traction to be applied (Fig 897) by means of a wire inserted through a hole drilled in the bone.

FIG 897
McGregor's apparatus for applying direct traction to a fractured mandible

THORAX

Fractured ribs—B Blades[5] is emphatic that the proper method to immobilize the chest wall in the case of fractured ribs is to place 4-in wide adhesive plaster to encircle the costal margin, as shown in Fig 898. If the

[1] Gelb, F W *Jour Amer Med Ass*, 1941, 117, 8
[2] Kintz, F P *Military Surgeon* 1941, 89, 60
[3] Gordon, J *Lancet* 1941 1, 788
[4] MacGregor, A B *Brit Med Jour*, 1940 2, 16
[5] Blades, B *Surg Clin North Amer*, 1940, 20, 1473

plaster is put on at the end of deep expiration it will not only limit the motion of the lower ribs but will be equally effective when the upper ribs are injured

In crushing injuries of the thorax when a number of ribs are fractured the alleviation of pain is a prior consideration Repeated doses of opiates depress respiratory function and invite pulmonary complications S Schnur[1] has practised successfully paravertebral injections of local anæsthetic

W D W Brooks[2] has found the Nuffield respirator useful in the management of multiple fractures of ribs It obviates paradoxical movement and overcomes dyspnœa from which these patients so often die

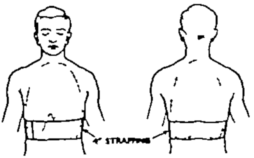

FIG 804

The correct method of strapping the thorax. It is immaterial whether upper or lower ribs are fractured. This universal method immobilizes the thoracic cage (*After B Blades*)

Open wounds—In severe open thoracic wounds M N Acutin[3] advises vago sympathetic block About 30 c c of ½ per cent solution of novocain are injected into the root of the neck through a point on the lower third of the anterior border of the sternomastoid A number of cases which appeared quite hopeless were saved thereby

C P Thomas[4] says that war wounds of the chest are second in their mortality rate only to abdominal wounds Radiological evidence is indispensable and anteroposterior and lateral films are both necessary Whenever possible operation should be performed within six hours of infliction of the wound The most important requirements for successful operation are a skilful anæsthetist a portable lamp within the thorax and an efficient rib spreader For the operation the patient lies on his side with a sandbag in the axilla Brock's chest piece will fit any table and is a valuable aid A thoracotomy wound of 6 or 7 in. is usually ample but the wound should be extended without hesitation to give sufficient access

Tension pneumothorax—J V Bohrer[5] says that treatment of tension pneumothorax is simple but it must be prompt Plunging a trocar and cannula between the ribs thus allowing entrapped air to escape is indicated in a real emergency This should be followed by the introduction of a catheter connected to a water-seal dressing or even more simply and more efficiently by what he calls a flapper tube This is a semi rigid rubber tube the extremity of which has been cut at an angle of 60 and a finger-stall is so attached as to act as a ball valve

Hæmothorax—B Linberg[6] gives the following instructions An increasing hæmothorax extending above the nipple line is dangerous In addition to giving transfusion aspiration with the removal of 200 to 300 c c is carried out and the same amount of air is injected care being taken not to alter the intrapleural pressure If after three hours it is considered that the hæmorrhage is continuing thoracotomy should be undertaken

Thoracotomy should not be performed unless there is evidence that the

Schnur S *Int Med* 1940 13, 843
Brooks, W D W *Brit. Med Jour* 1940, 2, 842.
Acutin, M N *Khirurgiya* 1940 10 2.
Thomas C P *Proc Roy Soc Med* 1940, 34, 83.
Bohrer J V *S rg Clin. North Amer* 1941 21 371.
Linberg, B. *Khirurgiya* 1940 1, 3.

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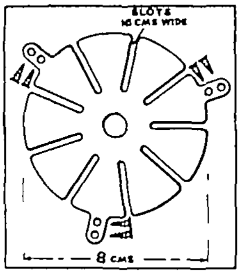

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[2] Kintz, F P *Military Surgeon*, 1941, 89, 60
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[4] MacGregor, A B *Brit Med Jour*, 1940, 2, 10
[5] Blades, B *Surg Clin North Amer*, 1940, 20, 1471

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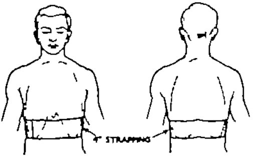

FIG 893

The correct method of strapping the thorax. It is immaterial whether upper or lower ribs are fractured This universal method immobilizes the thoracic cage (*After B. Blades*)

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[1] Schnur S. *Ann. Int Med* 1939 13, 845
[2] Brooks, W D W *Brit. Med Jour* 1940, 2, 842.
[3] Acutin, M N *Khirurgiya* 1940 10 3.
[4] Thomas, C. P *Proc Roy Soc. Med.*, 1940, 34 63.
[5] Bohrer J V *Surg Clin. North Amer* 1941 21 371.
[6] Linberg, B *Khirurgiya*, 1940, 1 3.

hæmorrhage is progressive, but aspiration with air replacement should be carried out within twenty-four hours In penetrating wounds early removal of the blood is essential, the condition being very liable to become infected [1]

J A Nixon [2] considers one of the most reliable signs of sepsis in a hæmothorax is an increase in the respiratory rate

Infected costal cartilages—J V Bohrer [3] states that infection of a costal cartilage following a stab wound is often progressive Its seriousness lies in the fact that sooner or later all the costal cartilages on the affected side become involved, and to effect a cure all must be resected

Respiratory exercises—J H Hughes [4] reminds us that an opening into the chest should not be allowed to close until complete obliteration of the underlying cavity has been confirmed radiologically by the injection of radio-opaque media Exercises of the MacMahon type are of great value in promoting expansion of the lung J A Nixon [2] considers that blowing exercises have no part in the treatment directed towards getting a collapsed lung to expand

Chylo-thorax—Of the rarer lesions, severance of the thoracic duct by a stab wound is of great interest This causes the so called chylo-thorax Cases have been reported in which enormous quantities of chyle have been removed Dietze reports a case in which 27 litres were removed in thirty-one days Hahn aspirated 29 litres during life and 7 litres at necropsy Fortunately, the thoracic duct often divides in its upper portion, and there is more than one stoma emptying into the subclavian vein For this reason some patients with a chylous leak in the thorax recover (J V Bohrer) [3]

C J Cellan-Jones and W Murphy [5] record a case of chylo-thorax in a miner aged 32, following an injury to the front of the chest Twenty-seven pints of chyle were aspirated in eight days. The patient died in a state of exhaustion on the ninth day Rupture of the duct is more likely to occur after a large meal, when the duct is distended with chyle Bauersfeld (1937) described a patient with chylo-thorax whose condition steadily retrogressed until the chyle recovered by operation was gravitated into the median basilic vein The general condition then improved steadily

WOUNDS OF THE ABDOMEN

Modern methods of waging war have increased the mortality of abdominal wounds On the other hand, this may be slightly counterbalanced by better and swifter modes of transportation to surgical aid

G Gordon-Taylor [6] finds that of hollow organs, the stomach and splenic flexure of the colon are most liable to injury

W H Ogilvie [7] says that it is unnecessary to trim the edges of a perforation before closing it

G Gordon-Taylor [6] considers that most wounds of the diaphragm in abdomino-thoracic injuries are in the sloping muscular portion of the diaphragm The rent is usually small—half an inch or less

B Linberg [8] advises that in thoraco-abdominal wounds the abdominal lesion be attended to by a separate laparotomy incision, and not through the diaphragm as some have recommended

W H Ogilvie [7] enunciates an important principle Minute particles of bombs and shrapnel may cause an intra-abdominal catastrophe by perforating a viscus Consequently, it should be a rule that every war

[1] Ministry of Health Instructions, Appendix B, 1941, 43
[2] Nixon, J A *Brit Med Jour* 1941, 2, 24
[3] Bohrer, J V *Surg Clin North Amer*, 1941, 21, 371
[4] Hughes, J H *Lancet*, 1942, 1, 303
[5] Cellan-Jones, C J, and Murphy, W *Brit Med Jour* 1940, 2, 590
[6] Gordon Taylor G *Brit Med Jour* 1941, 1, 802, 898
[7] Ogilvie, W H *East African Med Jour*, 1941, 18 67
[8] Linberg, B *Khirurgiya*, 1940, 1, 3

casualty presenting abdominal symptoms should be assumed to be due to an abdominal wound until it has been proved to be otherwise Thoracic wounds are often accompanied by considerable abdominal pain and rigidity the abdominal symptoms perhaps overshadowing those of the chest The main points of distinction are that in a purely thoracic wound the rigidity is strictly unilateral whereas if the abdomen is implicated also the rigidity is usually general Ogilvie favours the paramedian incision with splitting the rectus rather than dissecting and retracting in war surgery Before examining the abdominal contents it is wise to make a small nick in the peritoneum at the lower end of the incision If there is a considerable amount of intraperitoneal fluid the head of the table should be raised about 30 in and the nozzle of a sucker pushed into the pelvis to draw off as much fluid as possible before the peritoneum is opened The whole course of the small intestine having been examined when the perforation is found it should be marked by clipping a pair of forceps across the edge of the wound Ogilvie's advice regarding drainage is as follows always drain the extra peritoneal spaces and the outer layers of original abdominal wounds Always drain the peritoneal cavity not for present soiling but for trouble expected during the next few days Use vaseline gauze as a drainage material not rubber tubing Having drained do not be in a hurry to undrain

Fig 899
Spectacle frame holder for a gastric aspiration tube
(*After H E Isaacs.*)

H E Isaacs [1] has invented a spectacle frame (Fig 899) to hold in position a gastric aspiration tube This should prove of great general utility

Paralytic ileus—J S Horn [2] extols the Miller Abbott tube combined with continuous intravenous saline in a case of paralytic ileus following a bayonet wound

In paralytic ileus G M Novikov [3] injects ¼ per cent novocain about 50 to 70 c c into the posterior part of the abdominal wall in order to obtain bilateral block The patient is returned to bed and watched for an hour while the theatre is prepared Of 139 cases so treated 46 passed flatus and the symptoms were alleviated In another 25 instances this treatment combined with an enema brought relief If after an hour there is no response the probabilities are that the obstruction is mechanical and operation becomes essential Seventy-six out of 139 cases or 55 per cent were cured by the novocain method

Fæcal fistulæ—C F Dixon and J L Deuterman [4] find the use of suction invaluable For protection of the skin they erect about the fistula a rampart of adhesive plaster reinforced by a covering of a paste of kaolin and water

Secondary hæmorrhage—G Gordon Taylor [5] has found that secondary hepatic hæmorrhage is nearly always fatal

"**Blast abdomen**"—In deciding whether laparotomy should be performed in a case of blast abdomen W H Ogilvie [6] finds that auscultation is invaluable A silent abdomen is in need of laparotomy

[1] Isaacs, H E *Jour Amer Med Ass* 1941 116, 2345.
[2] Horn, J S *Brit Med Jour* 1940 2, 700
[3] Novikov G M *Khirurgiya* 1940 8, 66.
[4] Dixon, C F and Deuterman, J L *Jour Amer Med Ass* 1938, 111, 2095.
[5] Gordon-Taylor G *Brit Med Jour* 1941, 1 862
[6] Ogilvie W H. *East African Med Jour* 1941, 18, 67

N P Breden *et al* [1] describe the clinical features in ten patients suffering from under-water blast incurred from depth charge and torpedo explosions The brunt of the compression was manifest by abdominal signs and symptoms There was vomiting with moderate hæmatemesis, diarrhœa with melæna and considerable testicular pain in four cases Seven patients recovered without operation One recovered after drainage of a pelvic abscess, and one after drainage of a subphrenic abscess and an empyema One patient died after an operation for laceration of the small intestine In none of the nine survivors were there symptoms or signs of severe blast injury to the lung

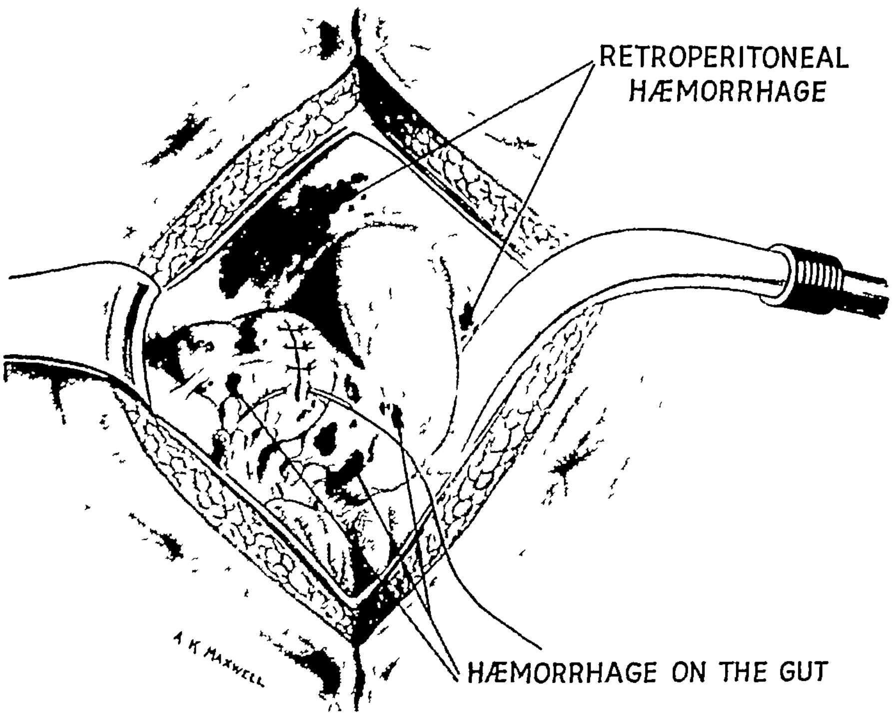


Fig 900

Rent in sigmoid colon due to blast being sutured with the aid of a curvlite retractor (*Vann Bros Ltd*)

C P G Wakeley [2] draws attention to the value of curvlite retractors (Fig 900), especially in abdominal and thoracic surgery They are invaluable when the electric current fails, as may well happen under war conditions, for their lighting is independent of the lighting in the operating theatre

RENAL INJURIES

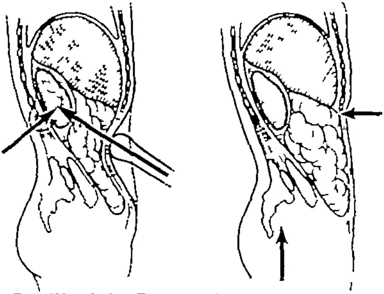
One of the results of ultra-mechanization of warfare is that the damaging factor tends to be a massive crushing force rather than a penetration In civilian practice, too, the increasing number of motor accidents has its bearing on injuries to the kidney There is a very definite increase in

[1] Breden, N P, *et al* *Brit Med Jour*, 1942, 1, 144 [2] Wakeley, C P G *Lancet* 1942, 1, 12

what P C Smith [1] calls third-degree damage to the kidney a damage which calls for clot evacuation and control of hæmorrhage or nephrectomy

In war wounds I feel that an attitude of ultra-conservatism would prove bad judgment for C Gordon Taylor [2] records that secondary renal hæmorrhage was a common complication in the 1914 18 war and Fullerton [3] found that 22 per cent of those patients who reached a base hospital had their lives jeopardized by this complication A H Peacock [4] referring to civil injuries states that the figures in favour of non-operative treatment are convincing O S Lowsley [5] comments on this situation as follows I am against this theory I believe it is conservative to operate early In cases of doubt a good rule is to follow that of O S Lowsley and J H Menning [6] who advise that every patient with an injury to the kidney who has hæmaturia for more than twenty four hours should have the injured kidney explored

M F Campbell [7] emphasizes that hydronephrosis stone and long-standing urinary infection are frequent predisposing factors in renal injury It is axiomatic that a diseased organ is more likely to suffer injury than a normal one



FIGS. 901 and 902. With a blow from the front the kidney is liable to be impinged against the 12th rib With a blow from behind it is thrown against the liver A a result of a fall the vascular pedicle is often damaged (*After Papin*)

J C Cheetham [8] shows that renal injuries (Figs 901 and 902) are more common in the male roughly in the ratio of 6 to 1 Excretory pyelography he says is becoming an accepted routine measure in every case of potential injury to the kidney In the absence of shock this may be done immediately The pyelogram may fail to show the kidney on the side of the injury but the presence or absence of a functioning organ on the other side will be disclosed

R J Swan [9] also remarks that an excretory pyelogram is very useful in showing the presence of a functioning kidney on the other side but he warns us that the pyelographic appearances on the injured side are often misleading especially when the renal pelvis contains blood clot and in some cases the excretion of dye is much delayed or absent I have found excretory pyelography most misleading in many of these cases but I agree with I Hareide [10] that it is the surest and easiest method of determining the condition of the unimpaired kidney (Fig 903)

[1] Smith, P G *Surg* 1941, 113, 6 1. [2] Gordon-Taylor G *Brit Jour Urol* 1940 12, 1.
[3] Fullerton, A. History of the Great War Surgery of War" 1922, 1, 556.
[4] Peacock, A. H. *Western Jour Surg.*, 1940, 48, 129
[5] Lowsley O S Year Book of Urology 1940, 104
[6] Lowsley, O S, and Menning, J H *Jour Urol.*, 1941 45, 253.
[7] Campbell, M F *Surg Clin. North Amer* 1941, 21 443.
[8] Cheetham, J G *Inter Abst Surg.*, 1941, 72, 5 1.
[9] Swan R J *Brit Jour Urol* 1940, 12, 161. [10] Hareide I *Acta Rad* 1940 21 492.

O S Lowsley and J H Menning[1] have found that many ruptured kidneys can be repaired The capsule is opened along the convex border, and clot and loose pieces of renal parenchyma are removed After constructing slots in the capsule after the manner shown in Fig 904, ribbon catgut is employed to bind the ruptured organ With this binding of ribbon catgut, together with muscle graft or pieces of perirenal fat, adequate hæmostasis can be effected in suitable cases Temporary nephrostomy is advisable in addition C M McKenna and J H Kiefer[2] warn us that in renal repair after trauma a high degree of clinical judgment is required to decide whether the kidney tissues are viable or not Procedure depends entirely upon the conditions found at operation

Fig 903

Excretory pyelogram in a case of ruptured right kidney
(*J F Brailsford*)

M F Campbell[3] advises that rather than take time to ligate a short or lacerated renal pedicle in the customary manner, it is occasionally good judgment to rely on hæmostats which are left on The wound is closed with minimum through-and-through non-absorbable sutures Clamps are

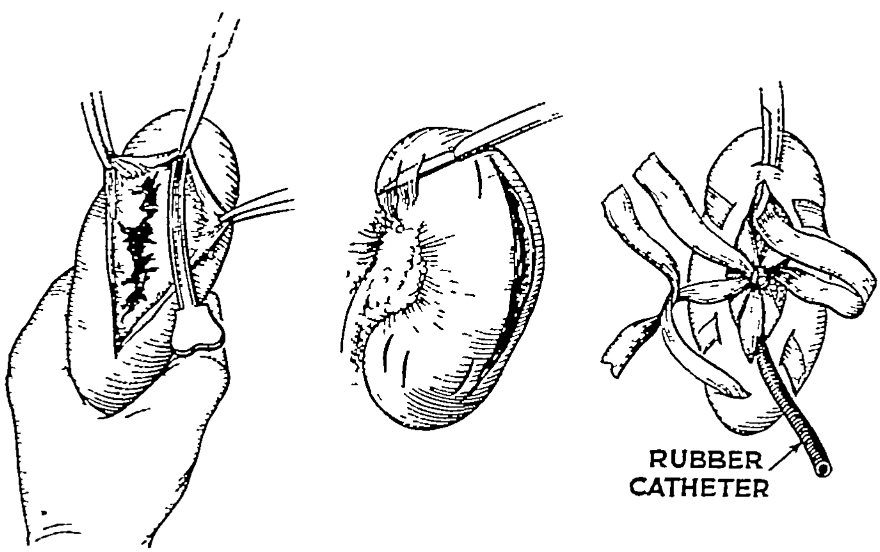


Fig 904

Repair of a ruptured kidney, using ribbon gut
(*After Lowsley and Menning*)

[1] Lowsley, O S and Menning, J H *Jour Urol*, 1941, 45, 253
[2] McKenna, C M., and Kiefer, J H *Jour Urol*, 1941, 45, 272
[3] Campbell, M. F *Surg Clin North Amer*, 1941, 21, 443

loosened on the third or fourth day and removed on the fifth. When polar injury seriously involves one-third of the kidney or less, partial nephrectomy is usually successful. Liberal nephrostomy drainage should be maintained in all resected or sutured kidneys until the urine is clear and the condition of the patient thoroughly satisfactory. This is a matter of at least ten days.

A. L. Lockwood[1] commenting upon gunshot wounds of the kidney says every effort should be made to save the kidney providing the artery, vein and ureter are intact and the organ is not badly shattered. While it is not easy or advisable to suture the spleen, the kidney capsule and perirenal fat often permit of encircling sutures which will control hæmorrhage from the renal cortex. Furthermore in this instance wide drainage can be instituted through a lumbar incision without harm resulting from pressure or contact with the tube. In secondary renal hæmorrhage there is no middle course between conservatism and nephrectomy (C. Gordon Taylor).[2]

When associated with other intra-abdominal injuries, particularly of the liver or spleen, a transverse abdominal incision is recommended by P. G. Smith.[3] This author also draws attention to the fact that reflex gastro-intestinal symptoms are due to trauma of the cœliac plexus. The so-called renal ileus rarely comes on until twenty-four hours after the injury. Fibrous perinephric changes may occur after perirenal hæmatoma. They cause chronic pain. Free liberation of the kidney from adhesions is indicated.

On wounds of the renal parenchyma and nephrostomy incisions—O. S. Lowsley and J. H. Menning[4] hope that the mattress suture for suturing the renal parenchyma will become obsolete. It causes so much destruction. There is often necrosis in that part of the kidney included in the mattress. The necrotic area sometimes separates and secondary hæmorrhage results. Binding the kidney by weaving ribbon catgut into the capsule is far more physiological. From experimental and clinical work A. Oberholtzer[5] has come to the conclusion that the control of hæmorrhage from a nephrotomy wound by applying a muscle graft is a safe operation capable of keeping the kidney in good anatomical and functional condition. C. C. Higgins and McC. Glazier[6] conducted a series of experiments on the kidneys of rabbits which show conclusively that in extensive nephrostomy incisions the diathermy cutting current has great advantages over the scalpel. There is less infarction and less extravasation of blood.

FRACTURED PELVIS, WITH SPECIAL REFERENCE TO RUPTURE OF THE INTRAPELVIC PORTION OF THE URETHRA AND THE BLADDER

Fracture of the pelvis (Fig. 905) has been common owing to the falling in of bombed houses. In many cases of fractured pelvis there is a rupture of the urethra (Fig. 906) (T. P. McMurray).[7] Air raid casualties have resulted in an increase in cases of bladder rupture, particularly of the intraperitoneal type (P. G. Smith).[3]

1 Lockwood, A. L., *Brit. Med. Jour.*, 1940, 1, 401.
2 Gordon-Taylor, G., *Brit. Jour. Urol.*, 1940, 12, 1.
3 Smith, P. G., *Surg.*, 1941, 113, 6?.
4 Lowsley, O. S., and Menning, J. H., *Jour. Urol.*, 1941, 45, 233.
5 Oberholtzer, A., *Helvetica*, 1940, 47, 400.
6 Higgins, C. C., and Glazier, McC., *Surgery*, 1941, 9, 220.
7 McMurray, T. P., *Lancet*, 1941, 1, 41.

Intrapelvic rupture of the urethra—A fracture of the pelvis can rupture the bladder or the intrapelvic portion of the urethra (Fig 907) in several ways by a direct blow, by penetration of fragments of the fracture, by separation of the symphysis pubis (A H Peacock)[1] In every case of rupture of the urethra the pelvis should be radiographed W R Hornaday[2] has found that a displaced spicule of bone sometimes gives valuable information concerning the location of a urethral tear J H Harrison[3] advises that in cases of intrapelvic rupture of the urethra, after an incision has been made above the pubis, blood and urine should be aspirated from the prevesical space The bony pelvis should then be manipulated into the best position An assistant exerting traction on the lower extremities may facilitate this procedure The bladder is then opened After a catheter has been inserted along the whole course of the urethra in the recognized manner, Harrison has the patient's legs flexed and slightly abducted He then performs perineal section so that blood and urine may be drained from the prevesical space dependently The patient is immobilized on a Bradford's frame A plaster cast is applied after several days when the patient's condition permits

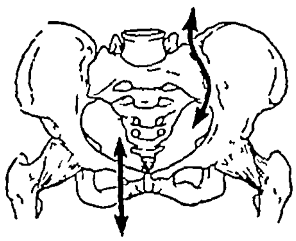


FIG 905
The oblique fracture of the pelvis is the variety which is most often complicated by rupture of the urethra
(*After G Gordon-Taylor*)

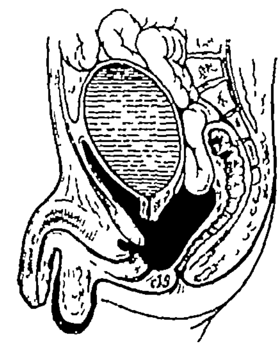


FIG 906
Intrapelvic rupture of the urethra Showing extravasation of blood and urine into the prevesical and rectovesical spaces
(*After Harrison*)

FIG 907
Usual sites of damage to the bladder and urethra
(*After A H Peacock*)

R Watson-Jones[4] writes that the plaster cast ought to be applied within two or three days at the latest Meanwhile the patient should be nursed in lateral recumbency and not on his back A double-hip spica should be put on with the patient in the lateral position (Fig 908) An orthopædic table, although an advantage, is not essential for this type of case There is little or no difficulty in accommodating the suprapubic cystostomy wound The margins of a fairly generous window are packed with vaseline gauze The same remarks apply to the perineal wound, if the hip on the normal side is abducted widely, the perineal wound can be attended to easily through the window in the plaster

When to remove the indwelling catheter in cases of intrapelvic urethral rupture is a difficult problem which has been solved by J H Harrison[3] in the following practical way A silk suture is used to change the catheter as necessary, by the railroad method After several weeks—up to six—a

[1] Peacock, A H *Northwest Med* 1940, **39,** 248
[2] Hornaday, W R *Jour Amer Med Ass*, 1940, **114,** 303
[3] Harrison J H *Surg Gynec and Obst*, 1941, **72,** 622
[4] Watson Jones, R 'Fractures and Other Bone and Joint Injuries,' 2nd ed Edinburgh, 1941

trial is made to see if it is safe to omit the catheter It is carried out thus The catheter is removed the urethra filled with radio-opaque medium and

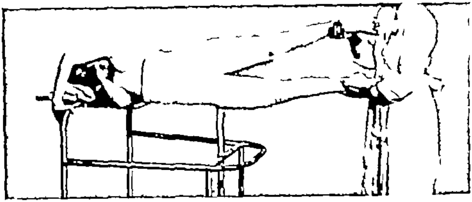


Fig 908

Method of applying double-hip spica in the lateral position. The patient lies on the relatively uninjured side (R Watson-Jones.)

a radiograph is taken with a portable unit If there is no extravasation of the opaque fluid the catheter is not replaced but the silk thread is still retained as a guide for the passage of instruments

For loss of continuity of the urethra such as that following on intrapelvic rupture with fractured pelvis C A Wells[1] makes a new urethral roof by cutting the distal end of the urethra as shown in Fig 909 Because of the difficulty of placing the stitches in the scar tissue near the bladder neck the new urethral roof is held in position by a single long catgut suture which is brought out through the suprapubic wound Here it is attached to an elastic band which in turn is stitched to the skin near the anterior superior spine By the time this catgut tension suture cuts through the new roof of the urethra has attached itself to its bed

Fig 909

A method of increasing the length of the urethra. (After C A Wells)

RUPTURED BLADDER

The principle reason why the mortality is so high is that an early diagnosis is not made H M Weyrauch and R A. Peterfy[2] find that the larger the opening in the bladder the easier the diagnosis for the popular method of running in a measured quantity of sterile saline solution and recovering much less quantity is then evident It is the small ruptures which are so dangerous because this test becomes fallacious Cystography is much more reliable The bladder should be fully distended with a radio-opaque medium and a portable X ray machine is used if the patient s condition is critical When there are reasonable grounds for suspecting a rupture it is safer to operate than to delay

N L. Bosworth[3] also stresses that the injection of an adequate quantity of a radio-opaque solution followed by a radiograph is the method of election

[1] Wells, C. A. *Brit Jour Urol* 1941 13, 8.
[2] Weyrauch, H M. and Peterfy R. A. *Jour Urol*, 1941 44 261
[3] Bosworth, N L., *Kentucky Med Jour* 1940 38, 200.

to confirm a suspected diagnosis If a portable X-ray unit is available, this method can be accomplished without moving the patient from the bed H Culver and W J Baker[1] prefer *injection of air into the bladder*, combined with radiography In cases of intraperitoneal rupture the air usually collects under the diaphragm, in other instances the pneumoperitoneum will be seen as collections of air pockets throughout the abdomen If the rupture is extraperitoneal, the air will be seen in the perivesical region They have not had any complications from the injection of air In twelve consecutive cases of rupture of the bladder admitted into the Cook County Hospital, Chicago, there was only one death, a tremendous improvement on the usual mortality figures for this condition.

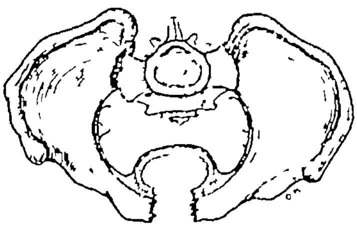


FIG 910

A tear in the bladder may be held apart by separation of the pubic bones (*R Watson Jones*)

P C Fleri[2] states that cystoscopy is the most reliable method of diagnosing a ruptured bladder In his opinion it is superior to radiographic methods [I know by experience that cystoscopy, even when it is performed by a competent urologist, is not invariably a reliable method of diagnosis in the case of a small tear or puncture —H B]

As Watson-Jones[3] points out, the tear in the bladder may be held apart by separation of the pubic bones (Fig 910), and no satisfactory approximation of the bladder wall is possible until the fracture-dislocation has been reduced

G Neligan[4] records that in the last twenty years at the London Hospital there have been ten cases of ruptured bladder, seven due to fracture of the pelvis and three during operations for femoral herniæ

Urethral fistula—E P Whelan[5] gives details of reconstruction of the penile urethra following wounds Very satisfactory results followed extensive lesions with loss of large portions of the corpus spongiosum An example of a sliding graft to close the defect at the penoscrotal junction is shown in Fig 911

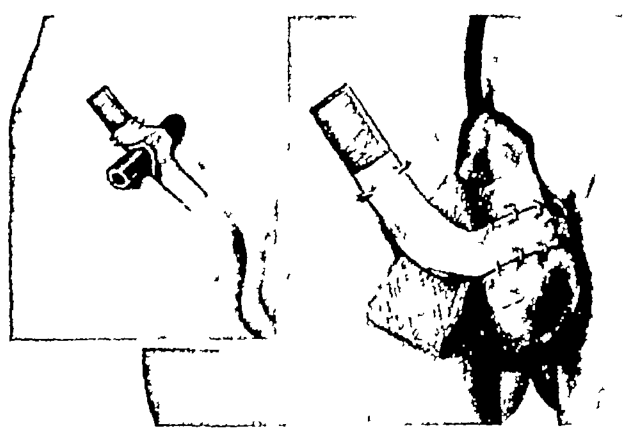


FIG 911

Sliding graft to close a defect at the penoscrotal junction (*After E P Whelan*)

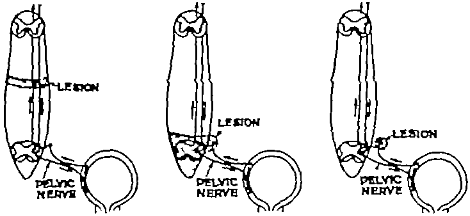
SPINAL CORD LESIONS—THE PARALYSED BLADDER

On the battlefield, on the highway, or in the factory, aseptic catheterization is usually impossible Overflow incontinence is more desirable than immediate catheterization (R M Nesbit and W G Gordon)[6]

[1] Culver, H, and Baker, W J *Jour Urol*, 1940, **43**, 511
[2] Fleri P C *Amer Jour Surg*, 1940, **50**, 661
[3] Watson Jones, R Personal communication
[4] Neligan G *Proc Roy Soc Med* 1941, **34**, 505
[5] Whelan, E P *Surg Gynec Obst*, 1941, **72**, 81
[6] Nesbit R M, and Gordon W G *Surg Gynec Obst* 1941 **72**, 328

F Hinman[1] says the best treatment of the paralysed bladder following severe injury of the spinal cord no matter what its location is to insert a suprapubic tube immediately providing it will be days or weeks before the victim reaches an institution where faithful and technical management by other methods can be instituted This is his considered advice to the war surgeon.

R M Nesbit and W G Gordon[2] show that traumatic lesions of the spinal cord and cauda equina may result in one of three types of bladder paralysis (Fig 912) —



A, Reflex bladder B Automatic bladder C, Atonic bladder

Fig 912
(After Nesbit and Gordon)

1 When the lesion is above the conus the so-called reflex bladder results The patient can neither initiate nor cause cessation of micturition, but is periodically incontinent

2 When the lesion destroys the conus or cauda equina the automatic bladder results Bladder muscle tone is increased and the internal sphincter is hypertonic The intravesical pressure is high and retention with over flow results

3 When the lesion destroys only the sensory pathways of the conus or cauda equina the atonic bladder follows There is dribbling from the bladder which possesses a low intravesical pressure and has no reflex activity

R M Nesbit and W G Gordon[2] state that patients with a reflex bladder whose intelligence allows them to adapt themselves to its periodicity can obtain a satisfactory degree of comfort and continence Those with the automatic bladder can sometimes be educated to empty the organ by manual suprapubic compression with straining In certain cases trans urethral resection of the internal sphincter aids this Presacral neurectomy theoretically should relax the internal sphincter and facilitate manual evacuation. Experience has proved that this measure is not effective Alternatively permanent suprapubic drainage must be employed Those with the atonic bladder have a relaxed internal sphincter permanent suprapubic drainage is therefore often necessary The ideal to be *obtained*

[1] Hinman, F *Jour Urol.*, 1941, 46, 490
[2] Nesbit R. M., and Gordon, W G *Surg Gynec Obst.*, 1941, 72, 328

for every patient with a neurogenic bladder is periodic evacuation of the bladder, with satisfactory urinary continence and the avoidance of urinary sepsis Small doses of urinary antiseptics when well tolerated are a further aid in controlling infection

C Huggins *et al* [1] find that good results accrued from presacral neurectomy in cases of vesical atony consequent upon lesions of the cauda equina or sacral cord in which the lumbar nerves were intact

H Thomas [2] has found that tidal drainage of the paralysed bladder is eminently satisfactory providing it is instituted at the beginning of the paralysis Tidal drainage is also useful in the treatment of chronic cystitis not due to paralysis

Cystometry, according to M Muschat,[3] was developed for one purpose only, to be able to state the presence or absence of a neurological disturbance of the urinary bladder The most practical gauge for use with a cystometer is the mercury manometer The pressure curve is remarkable for its constancy in the same individual over a period of many years To interpret cystometric study properly, three factors must be obtained. (*a*) the pressure curve, (*b*) the first desire to void, (*c*) the maximal voluntary pressure

INJURY TO NERVES

Causalgia—R J M Love [4] states that the burning type of pain (hence its name) is thought to be due to compression of the nervi nervorum. The condition is most commonly seen in association with the median and posterior tibial nerves Physiotherapy is harmful Severe cases may require sympathetic ganglionectomy

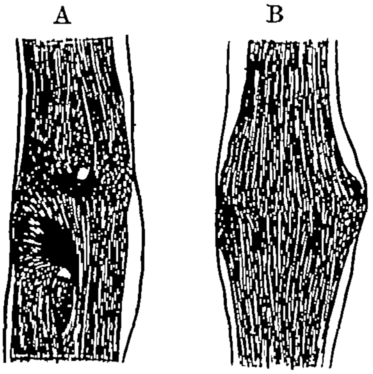


FIG 913

A, Sciatic nerve of a rabbit twenty-five days after junction made with fine silk sutures B, Sciatic nerve of the same rabbit twenty-five days after junction made with plasma (*After Young and Medawar*)

H Platt [5] says that two procedures, equally effective, have been used for this trying condition —

1 Intraneural injection of 60 per cent alcohol
2 Resection of the lesion and end to end suture

Nerve grafting—This is now on a sound basis Gaps up to 3 or 4 in have been successfully bridged For instance, 3½ in in the ulnar nerve was successfully grafted by J L Joyce [6] with a segment of the internal cutaneous nerve of the same limb

H Platt [5] advises that secondary nerve suture should not be undertaken until the wounds have been healed for at least six weeks, and the maximum possible nutrition has been restored by physical treatment In irreparable nerve lesions the choice lies in (*a*) bridging the gap by a nerve graft, or, (*b*) in certain lesions, restoring function by appropriate tendon transplantation

J Z Young and P B Medawar [7] have experimented in order to try to minimize the disorganization of nerve fibres which is produced by stitching, even if this is restricted as far as possible to the epineurium The method they have elaborated consists of gluing the cut nerve stumps with plasma which has just been mixed with strong tissue extract Details of the manufacture of the plasma and the tissue extract are given in their paper In about two minutes the plasma clots into a firm jelly, which sticks to the nerves and holds the stumps together, of course there must be no tension The experiments were carried out on the sciatic nerves of rabbits Histological studies are instructive (Fig 913)

[1] Huggins, C, *et al* *Jour Urol* 1939, 41, 696
[2] Thomas, H *Urol and Cut Rev*, 1941, 45, 147
[3] Muschat, M *Jour Urol*, 1940, 43, 582
[4] Love, R J M *Med Press and Circ*, 1941, 254.
[5] Platt H *Post graduate Med Jour*, 1940, 16, 256
[6] Joyce J L *Brit Med Jour*, 1920, 2 468 *Brit Jour Surg*, 1919 6, 418
[7] Young, J Z, and Medawar, P B *Lancet*, 1940, 2, 126

J Z Young *et al* [1] from experimental data and a review of the literature draw conclusions regarding nerve grafts. An autograft provides a medium for the growth of new fibres which is only slightly less satisfactory than a normal peripheral stump It is most important that the graft should be treated as a living thing and not pinched with forceps dried, or otherwise maltreated. The success of the thin Ballance and Duel grafts suggests that small nerves make better grafts than large nerves, and a cabled graft of several thin strands is probably better than a single thick graft which in any case is difficult to obtain Of twenty-one cases of autograft reported by O Foerster [2] there were five in which recovery was complete including two of the ulnar nerve twelve which were ameliorated two failures and two not traced

THE APPLICATION AND REMOVAL OF PLASTER-OF PARIS CASTS

Croft's plaster—John Croft (1833 1905) surgeon St Thomas's Hospital London invented the creamed fabric plaster After a suitable pattern had been cut of flannelette it was dipped in plaster cream and moulded to the limb The method fell into disuse It was revived by surgeons during the Spanish War Unfortunately, now that loose mesh flannelette is required it is not readily obtainable

W S Creer [3] gives instructions for making a hip spica from a standard three piece pattern cut out of seven layers of 24-in Cellona The use of borax in the water to retard setting is stressed.

G R Girdlestone [4] gives details for applying the creamed fabric plaster Three thicknesses of standard plaster muslin must be employed to replace one of flannelette An assistant can cut out the fabric while the surgeon is completing the operation.

CUTTING OUT THE FABRIC—Measurements of the part are taken from the sound side and 10 per cent is added to allow for shrinkage of the fabric The proper outlines are then pencilled on the top piece of the proper number of thicknesses and the material is cut out (Fig. 914)

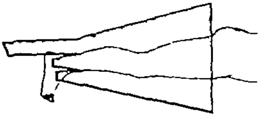


FIG 914
Pattern for Croft's plaster to encase the lower limb. (*After Girdlestone.*)

THE CREAM—The correct amount of warm water is placed in a hallow bowl. The plaster powder is quickly sprinkled over the surface of the water until it ceases to be absorbed, and lies on the surface For a lower limb plaster about 2 pints of water and 4 lbs. of powder are required. The assistant stirs and rubs the mixture into a cream and then passes the muslin pack slowly through the mixture lifts it up to drain for a moment, and then spreads it out on the table making sure that all the sheets correspond.

APPLICATION — Before the plaster sets it is moulded to the part and a thin layer of cream is spread evenly on the outside A few turns of bandage are used to hold it in place The edges of the fabric should not quite meet

The slab technique for the application of plaster casts using standard patterns saves time and mess Messrs T J Smith & Nephew Ltd have issued a useful booklet Preparation of plaster casts and offer a set of patterns to users of their wide Cellona material

Facilitating removal of plaster casts—W J Wilson [5] places a length of motor car fan belting longitudinally beneath the cast which is applied in the usual way The fan belting is greased so that it can be withdrawn when the plaster has set This leaves a groove in which to operate the blade of the plaster shears To ensure a good fit plaster slabs are placed on either side of the belting before the circular turns of plaster bandage are applied. M Shun-Shin [6] says that a length of rubber tubing is as effective as fan belting

[1] Young, J Z., *et al.* *Lancet*, 1940, 2, 128.
[2] Foerster O Handbuch der Neurologie, 1929 Teil 2, Abt. 2. Berlin
[3] Creer W S *Lancet* 1941 1 ?.
[4] Girdlestone G R. *Lancet* 1940 2, 237
[5] Wilson, W J *Jour Bone and Joint Surg* 1941 23, 1 ?
[6] Shun-Shin, M *Brit Med Jour* 194?, 1 508

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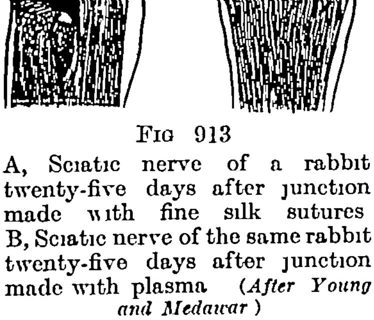

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[4] Love, R J M *Med Press and Circ*, 1941, 254
[5] Platt H *Post graduate Med Jour*, 1940, 16, 256
[6] Joyce J L *Brit Med Jour*, 1920, 2 468 *Brit Jour Surg*, 1919 6, 418
[7] Young, J Z, and Medawar, P B *Lancet*, 1940, 2, 126

Sensory disturbances accompany the muscular paralysis, but unlike this, are not permanent At first there is a "glove or stocking" anæsthesia to all forms of sensation With time the anæsthesia passes off; during recovery the patient may suffer much from a continued "pins and needles" sensation

Complications—The chief early complication is a massive liquefaction of the bloodless muscle probably the result of bacterial infection. Later complications include deformity due mainly to fibrosis, and atrophy of the still active part of the musculature from disuse.

Treatment—(a) By immediate recognition and relief of the arterial obstruction the onset of ischæmic paralysis may be forestalled. This is particularly the case with fractures about the elbow the radial pulse being a useful indicator

(b) When ischæmic paralysis has already occurred, the prevention of deformity and the maintenance in good condition of the still active muscular tissue will be the chief aim of therapy Later tendon lengthening and so forth may be called for

AMPUTATIONS

"Especially valuable i the chapter on general principles of amputations by Sir William de Courcy Wheeler"—*Australia and New Zealand Journal of Surgery*

"If we are to have modern warfare let us have modern surgery and not be quoted examples of the surgery of 1801"—*Guy's Hospital Gazette*

(Excerpts from reviews of the first edition of this work)

In the first edition I wrote "It has been my endeavour to guide the reader but at the same time by sweeping aside bigotry to encourage him to think for himself and add to the common stock of knowledge This can only be done by presenting two sides of the question Take for instance the subject of amputations. The reader can see for himself the arguments of the two schools of thought"

This i indeed a world war and the world is wide Those whose horizon is limited to the Roehampton school harken to Professor Gallie [1] who speaks after an experience based on 2,448 amputations of the lower limb

Professor Gallie a member of the Canadian Pensions Board states categorically that the Syme amputation is the most satisfactory of all amputation stumps That the mid calf stump is not by any means ideal for this stump is often blue and painful and will not withstand the ordinary hazards of life unless the patient rests for part of the day too often the patient complains of phantom limb or other disability Many Canadian pensioners have had to submit to re-amputation He further states that the Stokes Gritti stump will withstand many years of hard wear

Hear also what the President of the Association of Limb Makers of America has to say C C Haddan [2] favours the Syme amputation above all amputations as it gives an excellent weight bearing stump He also considers that the Stokes Gritti amputation gives an ideal end bearing stump for fitting an artificial limb

R I Harris [3] states that it cannot be too strongly emphasized that the end bearing amputations of Syme and Stokes-Gritti are greatly superior to all other forms in the lower extremity The Stokes Gritti amputations in Canada have given entire satisfaction to the patient the surgeon and the limb maker Syme s has the same merits below the knee as the Stokes Gritti above it It is essential that the patella should be firmly fused to the femur without tilt or lateral displacement It is a source of amazement to Harris and his Canadian colleagues that the British Ministry of Pensions in a recent brochure should condemn weight bearing stumps He can attribute its experience only to poor artificial limb making The Canadian Government established its own limb making factory which is still working This resulted in direct control by the surgeons who dealt with the amputations

[1] Gallie W E Ann Surg 1941 113, 925
[2] Haddan C C Rocky Mountain Med Jour 1940 37 440
[3] Harris R I Jour Amer Med Ass 1941 116, 3?9

R G Bickford's[1] method consists in laying on the limb before the application of the plaster a length of 24-gauge piano wire, a shilling roll of which is sufficient for about ninety cases To prevent injury to the skin the wire is applied over stockinet The wire is bent back at either extremity of the plaster and held in position by strapping The wire rusts slightly, but this has little effect on its efficiency The wire is capable of cutting through thirty layers of Cellona plaster bandages, a thickness of $1\frac{1}{2}$ in of plaster To remove the plaster cast one winds out the wire over an old pair of Spencer Wells The winding must be strong and even, since sudden jerking may snap the wire

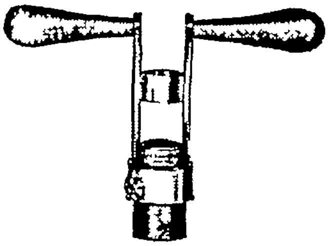

Fig 915
Gowland's plaster trephine
(*Allen & Hanburys*)

M M Gowland[2] has often seen low-grade infection developing after the removal of skeletal traction pins He has also experienced difficulty in removing plasters where pins are *in situ* The plaster trephine (Fig 915) proved useful in removing sufficient plaster around the pin to allow the area to be cleansed before removing the pin, this does not reduce the strength of the cast The trephine can also be used for exploring in cases of suspected pressure sore

For protecting bony points under plaster casts, pads of $\frac{1}{4}$-in sticky white felt are usually recommended W A Cochrane's[3] preference is for Gamgee, because felt, especially the grey variety, may contain tetanus spores If felt is used it should be sterilized, and so should stockinet

To maintain proper elevation of a limb in plaster, S Sideman[4] finds pillows and sandbags are unsatisfactory, as they require constant attention Two pieces of wood 12 in long and 1 in wide and deep are nailed together to form a cross By adjusting the cross with a wide base, moderate elevation is obtained, with a narrow base, higher elevation For ordinary purposes a right-angled cross is used The cross of wood is incorporated in the plaster bandage with the result shown in Fig 916 This appears to be a very simple and useful piece of technique

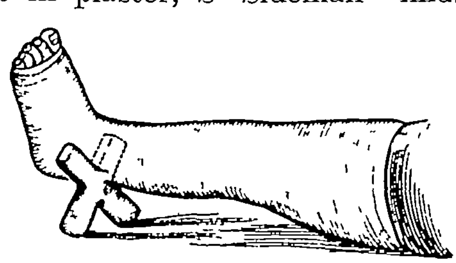

Fig 916
Wooden elevator incorporated in a plaster cast (*After Sideman*)

TRAUMATIC ISCHÆMIA OF MUSCLES

Traumatic ischæmia of muscle has been investigated by Harold Burrows[5] Apart from gangrene, two muscular disabilities may be caused by a reduction of the blood-flow —

1 Ischæmia without paralysis—A limb afflicted in this way is wasted, and when exercised soon becomes tired and subject to cramp

2 Ischæmic paralysis—Volkmann (1881) attributed this condition to a deprivation of arterial blood leading to coagulation and destruction of the voluntary muscle fibres The correctness of Volkmann's views on the etiology seems to be established (Griffiths)[6]

Physical signs—The absence of a distal pulse is the most important sign, for it can be recognized before ischæmic paralysis has ensued Shortly after the obstruction of a main artery, the hand or foot may be cold and pale or cyanosed, with time, reactionary cutaneous vasodilatation occurs

The onset of *muscular paralysis* is rapid and may be complete within the first twenty-four hours or less When exposed, the ischæmic muscles are seen to be altered in hue, retaining hardly a tinge of red

[1] Bickford, R G *Brit Med Jour*, 1940, 1, 539
[2] Gowland, M M *Lancet*, 1940, 2, 136
[3] Cochrane, W A *Lancet*, 1940, 2, 146
[4] Sideman, S *Jour Bone and Joint Surg*, 1939, 21, 1045
[5] Burrows, H Personal communication
[6] Griffiths, D Ll *Brit Jour Surg*, 1940, 28, 230

states that in amputations in infected cases it is a wise precaution to leave main arteries long and having inserted a circular suture in the adjacent muscle to approximate this overcoat over the end of the artery In this way the liability of secondary hæmorrhage is reduced

The prevention of "spurs"—Removal of a cuff of periosteum of 1 in in depth diminishes the chances of development of a terminal exostosis Fascia or a broad flat tendon makes an ideal covering for a stump but muscle over the end of the bone usually becomes converted into fibrous tissue and adheres to the scar [1]

Amputating in poor risk patients—H A Brittain [2] finds that amputation performed in the patient s bed may prove a life-saving procedure as it prevents the shock entailed by the journey to the theatre and the disturbance of a continuous blood transfusion which is working smoothly The guillotine operation is the one of choice in these severely shocked patients After the limb has been sectioned as expeditiously as possible the main vessels are tied Generalized ooze is ignored and being satisfied as to the hæmostasis of arteries the tourniquet is tightened while sulphonamide powder is dusted on the raw surface Vaseline gauze and wool are then applied and bandaged tightly The tourniquet is then removed

AFTER-TREATMENT

Above-knee amputations [3]—After operation the stump should lie flat on the bed and not on a sandbag or pillow The latter predisposes to flexion of the stump which is a great disability [Sir William Wheeler s method of applying a plaster cast to the stump described in this work is an excellent preventative of flexion —H B] As soon as the dressing has been removed crêpe bandaging should be commenced (Fig 918) A 6 in crêpe bandage should be applied firmly from below upwards pressure around the stump being gradually eased as the bandage is carried upwards as high as possible The object is to produce a conical stump

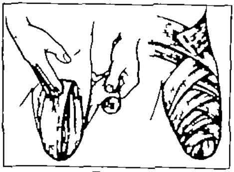

Fig 918

(a) Three applications of bandage to support the tissue stump
(b) Compression bandaging from the lower end *upwards* around the abdomen, to give support over the whole tissue of the stump—to the perineum also
(*After E M S I structions.*)

Skin traction—F B Thomas [4] suggests what would appear to be an excellent method After washing the stump thoroughly with soap and water and drying it with spirit and ether a length of well fitting stockinet is then pulled over the skin to cover its distal 6 in. After all the creases have been smoothed out the stockinet in contact with the skin is painted liberally with Benzo Mastiche (Martindale) to within 1 in of the skin edge The stockinet is then left for twenty four hours to dry when a length of blind cord is tied to a knot in the stockinet 1 ft from the end of the stump The

1 Annotation *Jour Amer Med Ass*, 1940, 115, 1799
2 Brittain, H A *Brit. Med Jour* 1941, 1, 10
3 E.M.S Instructions, 1941.
4 Thomas, F B *Lancet*, 1940 2, 310

T B Mouat[1] writes "I have done many Syme's amputations, and I think very highly of the operation, especially for a working man I always follow Syme's directions, and keep the anterior incision from the tip of the external malleolus to a point ½ in below the tip of the internal malleolus It is dangerous to teach younger men to commence the incision behind the tip of the internal malleolus, because this may imperil the blood supply of the flap"

Above-knee amputations—The best stump of all measures 10 to 12 in from the tip of the great trochanter[2] The best scar is a posterior transverse one, lying about 1½ in above the extremity of the shaft of the bone It is an advantage if the hamstring muscles are cut 1 in higher than the skin, there is no chance then of them becoming adherent to the scar

Below-knee amputations—The best site is a 6-in stump of tibia with the fibula cut 1 in shorter Anteroposterior flaps are best, the anterior being twice the length of the posterior It is essential that the anterior edge of the tibia be bevelled[2]

The guillotine amputation—W H Ogilvie[3] states that adhesive straps are fixed to the skin The wound is dressed with vaseline gauze, and tapes tied to the end of a Thomas' splint Within twenty-four hours all the straps except the anterior ones are soaked off by discharge, and must be reapplied On the third day the patient is evacuated He arrives at another hospital with all the extensions off and the stump is already conical

W H Ogilvie[4] has evidently very strong views about the guillotine amputation, for he writes "The guillotine operation is a crime which no conceivable surgical or military circumstance can justify" C Max Page[5] says that the guillotine amputation in its crude form is seldom necessary, and the subsequent dressings are always painful, and secondary hæmorrhage is common Page advocates the use of a short, circular flap, cut obliquely so that one flap overlaps the bone end The cavity is packed with vaseline gauze S Barling[6] finds that guillotine amputations are apt to be unsatisfactory and cause prolonged and painful convalescence

Amputation of digits—L Rogers[7] illustrates the preferable sites (Fig 917) For the thumb he agrees that it is essential to save all possible When it is not feasible to save a stump of the middle or ring finger, total amputation with sacrifice of the head of the metacarpal is preferable to disarticulation Removal of the head serves to keep the correct alignment of the other digits, so that these do not deviate towards each other Contrary to what is often taught, removal of the head and neck of the metacarpal bone does not materially weaken the hand

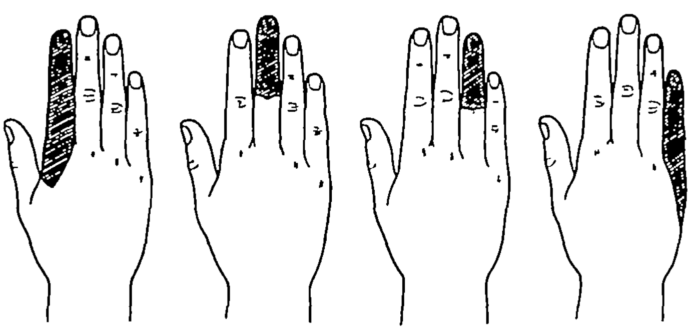

Fig 917

Preferable sites for digital amputations (*After Lambert Rogers*)

A precaution when amputating in infected cases—A L Lockwood[8]

[1] Mouat, T B Personal communication
[2] E M S Instructions, 1941
[3] Ogilvie, W H *Lancet*, 1940, 2, 212
[4] Ogilvie, W H *Guy's Hospital Gaz*, 1940, 54, 212
[5] Page, C M *Brit Med Jour*, 1939, 2, 77
[6] Barling, S *Post-Grad Med Jour*, 1940, 16, 162
[7] Rogers, L *Jour Royal Nav Med Serv*, 1941 27, 137
[8] Lockwood, A L *Brit Med Jour*, 1940, 1, 445

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A

cord is carried over a pulley and attached to a 4-lb weight (Fig 919) Stockinet applied in this way will stand a pull of 4 lbs for a week or ten days If it is necessary to inspect or treat the end of the stump, the cord and the weight are removed and the stockinet can be untied and turned back over the stump

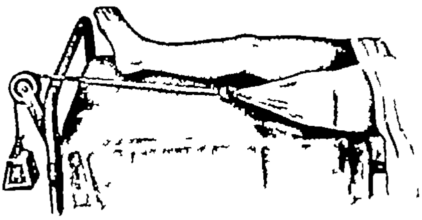

Fig 919
Skin traction applied by means of stockinet (*After F B Thomas*)

Painful amputation stumps—In phantom limb G M Novikov [1] performs circular nerve block with $\frac{1}{4}$ per cent novocain The novocain is injected around the limb in the middle of the stump Of 40 cases so treated, 35 needed only one injection, 4 had two and 1 had three In 30 cases there was a lasting cure, in 3 considerable improvement

MISCELLANEOUS ITEMS

Blank cartridge wounds are not without their dangers The powder burn of the skin is frequently associated with entry into subcutaneous tissue of some portion of the wad The wad is made of felted cattle hair, and often contains spores of tetanus and other organisms (C W Cutler) [2]

Parachute injuries—W J Tobin [3] found that of thirty two consecutive parachute injuries, 78 per cent sustained fractures, mostly of the lower third of the leg

R Watson-Jones [4] says that in the R A F compression fractures of the spine are not uncommon after parachute descents or when the spine is forcibly flexed in a crash landing

PATHOLOGICAL SPECIMENS

Most of the famous collection of specimens illustrating injuries of war housed at the Royal College of Surgeons were destroyed by enemy action It is most desirable that this collection should be replaced Professor Geoffrey Hadfield, Hill End Hospital, St Albans, Herts, will be grateful to receive suitable specimens for the purpose

Fixation should be carried out in a convenient receptacle such as a bucket (only if enamelled or tinned), a basin or a jar, the volume of the receptacle should be at least twice and preferably three times that of the specimen This ensures that the greater part of the weight of the specimen is supported by the fluid, but cotton wool should be placed at the bottom of the receptacle to prevent flattening Bottles with relatively narrow necks, through which specimens would need to be forced, should be avoided The receptacle should be covered with a lid, but need not necessarily be tightly corked

The fixative used should be 4 per cent formol saline Stronger solutions do not give better fixation and tend to inhibit penetration of the tissues In the case of solid organs, with the exception of the brain, the fixative never penetrates more than about $\frac{1}{4}$ in For this reason all dissection and trimming should be carried out before fixation is completed [5]

[1] Novikov, G M *Khirurgiya*, 1940, 8, 66
[2] Cutler, C W *Surg Clin North Amer*, 1941, 21, 485
[3] Tobin, W J, *et al* *Jour Amer Med Ass*, 1941, 117, 1318
[4] Watson Jones, R *Proc Roy Soc Med*, 1941, 34, 454
[5] Special article *Lancet*, 1941, 2, 647

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Spinal cord
Injuries

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